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METAL PROGRESS

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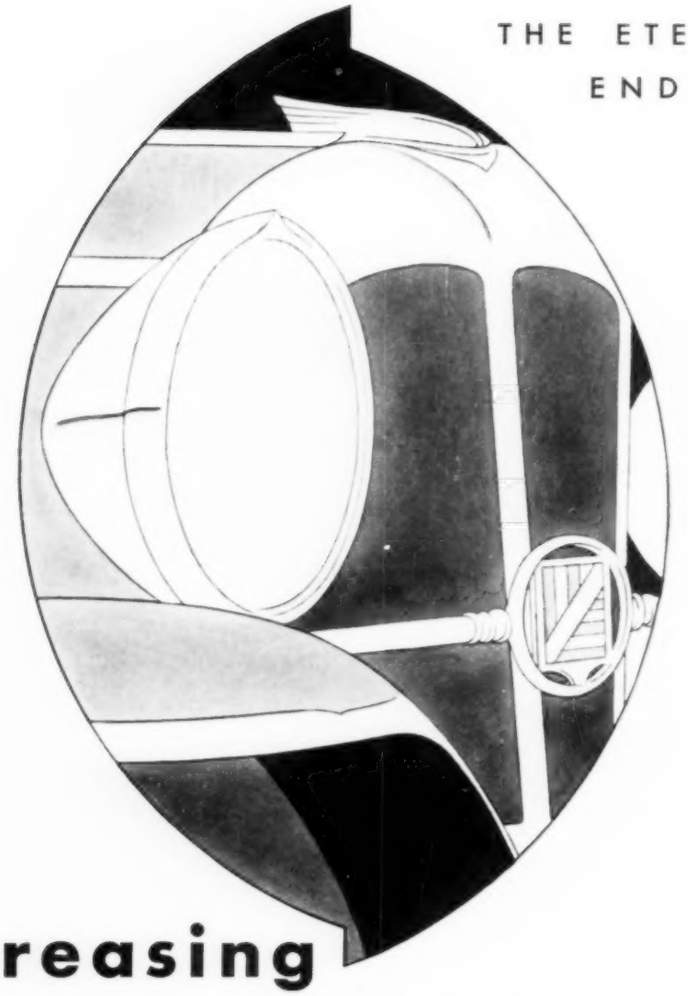

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Central Alloy Division

REPUBLIC STEEL
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METAL PROGRESS

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Ernest E. Thum, Editor

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Hot Iron Into the Mixer

OXYGEN

in solid steel

Campbell Memorial Lecture

by Marcus A. Grossmann

THERE are numerous forms which oxygen may take in solid steel, and the total amount may vary within wide limits; therefore a reliable method of determination is of paramount importance. There is but one method which is wholly reliable, namely, that developed by Jordan, which involves melting the sample in a carbon crucible in a vacuum. At this high temperature the oxides in the now molten steel react with carbon from the graphite crucible, forming CO gas, which passes off, is absorbed and weighed. A sample of open-hearth iron analyzed by this fusion method by scientists in Washington, Aachen and Sheffield, showed 0.058, 0.059 and 0.055% oxygen.

We are therefore in a position to determine what content of oxygen is usual in steel. Several hundred determinations of steels (steels made on a commercial scale and cast into ingots weighing from 1.5 to 5 tons each), show that there is no general normal which applies to all steels, but that, on the contrary, there are different values to be expected, depending both on the composition of the steel and on the manner in which it was made.

A representative value for low-oxygen steels would be around 0.007%; steels of the high-oxygen type would contain perhaps 0.040 to 0.060%. Other types have intermediate values, say from 0.010 to 0.030%. Steels are found to deviate as much as perhaps 30% from the normal for their class, but no instance has been observed where a type of steel containing normally 0.040% contained as little as 0.008, or vice versa.

A mere stating of the oxygen content of a piece of steel has no significance unless we know the effect of the oxygen on the steel. This is the question which we propose mainly to discuss.

A mention of oxygen in steel is likely to bring to mind first of all the oxides, the non-metallic inclusions, the particles which are observable under the microscope and which generally arouse at least a shudder in the observer.

Indeed, the common assumption, that the presence of such oxide particles might affect the mechanical properties of the steel, seems reasonable enough. As a result, a number of investigators have, in recent years, carried out an enormous amount of work on the effect of inclusions, both as to the numerical value of the mechanical property studied, and as to the manner of failure of pieces tested to destruction.

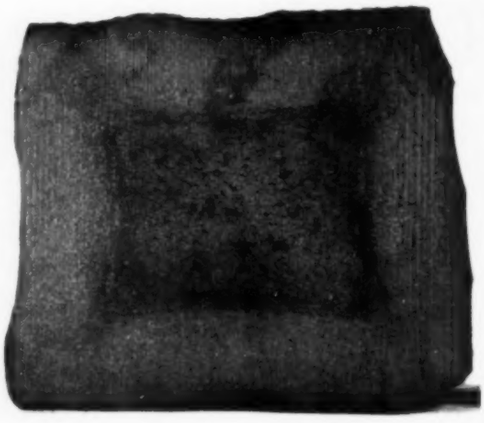
But there is also another direction in which we may look for effects of oxygen on the properties of steel. Steel

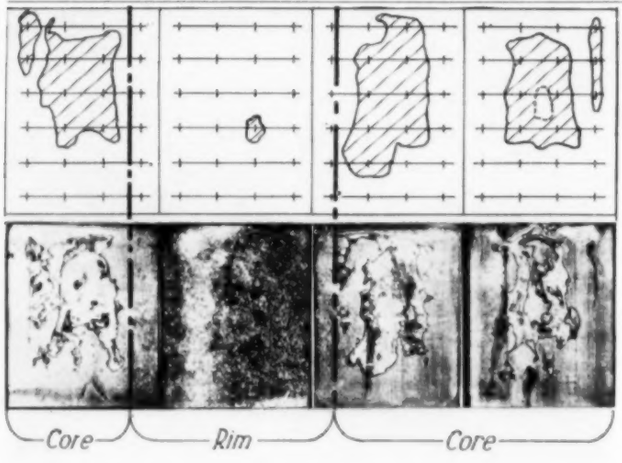
is an alloy of iron and carbon, and the properties of steel are due in large measure to the behavior of the carbon and its effect on the iron. It is here that we may look for an effect of oxygen, namely, its possible influence on the behavior of carbon in steel treating reactions. And so your speaker has led you triumphantly to the subject that he really wishes to talk about.

There is at hand a group of data which we presumptuously hope you will consider imposing, and which points to the hypothesis that oxygen is soluble in steel because the quantity of oxygen contained in the steel is increased during a heat treatment.

The heat treatment to which we refer is carburizing in a packing mixture of the charcoal type. If we wonder how such a carbon mixture could lead to absorption of oxygen, we must remember that the actual carburizing agent in such a mixture is probably CO gas, the charcoal being the source from which this gas is generated. Carbon splits off from the gaseous compound, dissolves in the iron and is absorbed, leading to the familiar rise in carbon content. And the interesting point for our present consideration is that a certain amount of the oxygen seemingly splits off in the same way and is absorbed in the steel, for there is an increase in the oxygen content also.

Test Blocks Were Cut so That Half the Volume Was From the High Oxygen Core of This Billet, Half From the Low Oxygen Rim. After carburizing, the material from the rim hardened completely, but the core developed soft spots.





Since the first discussion of this fact two years ago, there has been much confirmatory evidence. Our own results show that the oxygen content of various samples increased during carburizing by amounts varying from 0.001 to 0.026%. Of other work, the most extensive list we have found is that of Dr. Treinen of Aachen, Germany, from whose data we note oxygen absorption in every case. A few further data, published by Diergarten of Aachen, show the same effect.

If this listing of results has savored of "Methinks he doth protest too much," we must reply that the phenomenon was unexpected and that it leads to far-reaching results, and we therefore welcomed confirmatory evidence.

The question whether the oxygen is truly in the dissolved state is a theoretical matter awaiting further evidence. A more practical point, to which we now come, is the effect of oxygen on the hardening and the structure of steel. Here the facts speak for themselves, and

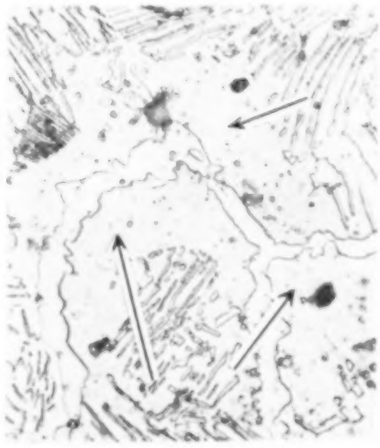
we shall find, like the rain which falls on the just and on the unjust, that oxygen affects alike the steel of the technician and of the theorist, whether the person doing the steel treating thinks *his* oxygen is dissolved or precipitated, or even colloidal.

Now the easiest way to look for an effect of oxygen on the hardening of steel is, obviously, to compare steels which are alike in composition except for their oxygen content.

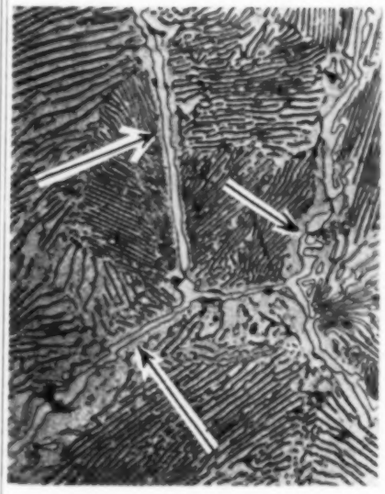
In order to secure steels substantially alike in manganese and silicon, and yet varying in oxygen content, the following simple circumstance was made use of: It is known that in "open" steels (steels which give off gas during the solidification of the outer portion of the ingot), the core is higher in oxygen than the rim, due to the different manner of solidification in the two portions of the ingot. We thus have in the same ingot two portions of the same mass of steel, the two portions presumably alike in other elements, but differing in oxygen content.

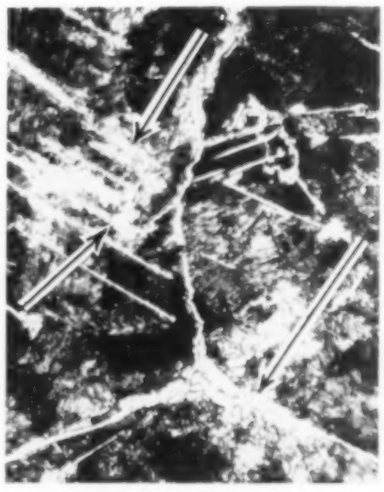
A billet from an ingot of such steel was selected for test and was analyzed. The carbon (0.025%), manganese (0.18%) and silicon (0.01%) are practically identical in the two portions but the oxygen is three times as high in the core as in the rim (0.067 and 0.018% respectively). An etched cross-section of the billet is illustrated on the opposite page.

In proposing to compare the hardening power of the rim and core materials varying only in oxygen content, we recall that the carbon is, of course, much too low to give any great hardness upon quenching. We consequently propose carburizing the test blocks so as to have high-carbon faces which are therefore hardenable. This may be condoned because a number of the experiments to be described have also to do with carburized steels.



Normal Steel at Left; Abnormal at Right. Both cooled in 45 min. The outstanding difference is that the structure of normal steel consists of pearlite, bounded sharply by films of cementite, whereas in abnormal steel there are large areas of free ferrite between the pearlite and the boundary cementite.





The Same Two Steels Were Cooled From the Pot at Such Rate That the Boundary Ferrite is About Equal. They have such extraordinary differences in rate of carbon diffusion that the normal steel had to be cooled over a period of 5,000 min. to develop the same amount of free ferrite as develops in abnormal steel in one.

Before proceeding to the hardness tests after carburizing, we must remember that it is the oxygen content whose effect we are studying, and that the oxygen content changes during carburizing. We must therefore analyze the rim and core materials *after* carburizing. Thin pieces, ⅛-in. thick, were carburized all the way through, for it seems probable that the oxygen content of these thin pieces after carburizing is a good approximation to the oxygen content of the carburized surface layers of the blocks we shall test for hardness.

Oxygen analyses were made and the thin piece cut from the rim (originally 0.018% oxygen) had increased to 0.046%, and the core pieces carburized (before: 0.067; after: 0.092) still have a very much higher oxygen content than the rim pieces.

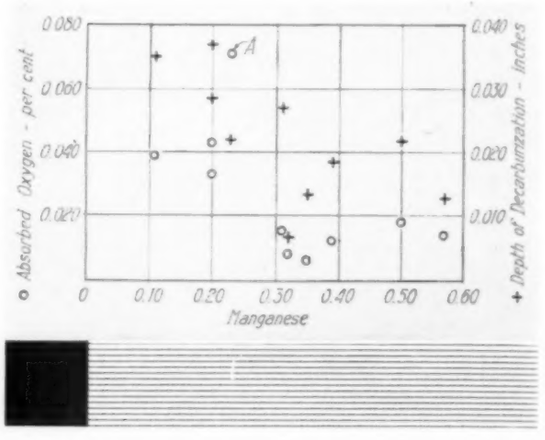
Having determined these facts, test blocks could be prepared for hardness testing. This block (originally used by Rawdon and Epstein at the Bureau of Standards to secure data of this kind) is 1½ in. square by 2 in. high. It will harden all over to above Rockwell 60-C if made of normal high-carbon steel and quenched in cold water. Systematic examination for hardness is made by testing 21 spots on each face, according to templet.

Each block was cut so as to be about half rim and half core. They were carburized 8½ hr. at 1690° F. and quenched from the pot into still water at 65° F. Hardness readings for the four faces of a block were listed, and corresponding diagrams were constructed as shown in the upper half of the view on page 34. Cross-hatched areas are regions in which all of the hardness readings were less than Rockwell 60-C, whereas the remaining light areas are regions which were above 60-C (file-hard).

Another method of locating soft spots is to etch the blocks in acid, since the difference in etching between the soft spots and the hard parts is very marked. The block described was so etched, and the photographs of the four faces are shown in the lower half of the cut.

It will be observed that one of the faces, the second counting from the left, is practically free of soft spots, this behavior extending a short distance along the two adjacent faces, and we note that this is brought out both by the hardness testing and by the etching. This hard portion

Ten Experimental Heats of Steel, All of a Low Carbon Carburizing Type, Which Had Various Manganese Contents From 0.11 to 0.57%, But Otherwise Quite Alike, Were Analyzed as to Oxygen Contents Before Carburizing and After. It appears from the results that manganese prevents absorption of oxygen during pack carburizing. When these same steels are heated in a carbonaceous mixture at a temperature where the tendency is to decarburize, it is found that the ones low in manganese also are decarburized to the greatest depth.



was the rim portion of the block, that is, the portion lower in oxygen. The rest of the block, the core portion, showed large soft spots, and the proneness to soft spots after carburizing and hardening seems attributable to the larger amount of oxygen present in this core portion.

Cause of Soft Spots

Now up to this point, after having mentioned briefly the amounts of oxygen that are commonly found in steels, we have considered a little evidence that oxygen may sometimes be in the dissolved form, and also some evidence that oxygen may at times affect profoundly the hardening power of a steel in which it is contained.

We come now to what has seemed to be a critical group of experiments, indicating that oxygen in the dissolved form takes on the proportions of a new monster just rearing its head above the metallurgical horizon. As a matter of fact, certain interesting behaviors in steel *can* seemingly be attributed to this new bogie.

We revert here to the classical experiments of McQuaid and Ehn, who discovered a rela-

tionship between the tendencies of carburized steel to form soft spots instead of hardening in quenching, and the microstructures exhibited by those steels after slow cooling. The outstanding difference between the two structures, slowly cooled in the carburizing pot, is shown in the micrographs on page 35. McQuaid and Ehn came to the conclusion that oxides in the steel were responsible for the abnormal condition, a conclusion thought "not improbable" by Prof. Edward DeMille Campbell, as expressed in a letter to Mr. Ehn.

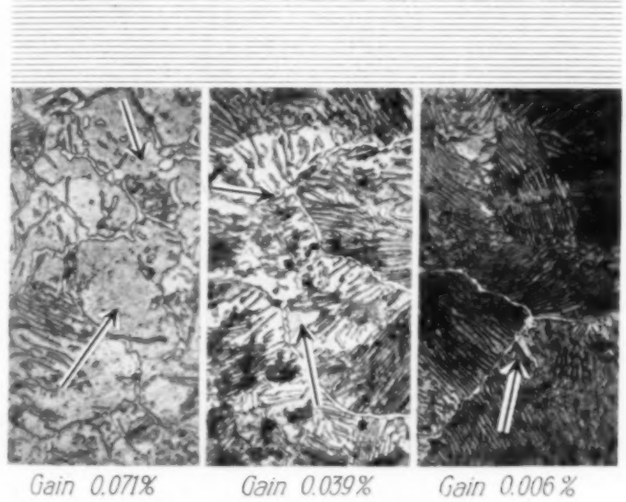
A suggestion by Dr. Merica resulted in our obtaining some evidence (presented on a previous occasion) indicating that the free ferrite observable in abnormal steel was in an area which had been previously occupied by pearlite, and that the cementite from this lamellar pearlite had diffused out to the boundary hypereutectoid cementite and had deposited upon it.

But if the pearlite in the *abnormal* steel loses its cementite by diffusion to the boundary, one might reasonably suspect that there is a tendency for such diffusion to take place even in normal steels, and that something conspires to defeat it.

Now we know that, if abnormal steel is cooled quickly from the carburizing heat instead of slowly, the amount of free ferrite which we find in the structure is then much less; that is, the pearlite is not decomposed so much by diffusion. In other words, by decreasing the time of cooling, during which the separation (the diffusion) takes place, we decrease the amount of free ferrite in the abnormal steel, and consequently, by increasing the time, we increase the amount. Reverting now to the *normal* steel, if this steel too has a tendency, even though slight, to permit diffusion to take place, then perhaps we could, by prolonging the time of cooling, create conditions which would allow the diffusion of cementite and the occurrence of free ferrite, even in this normal steel.

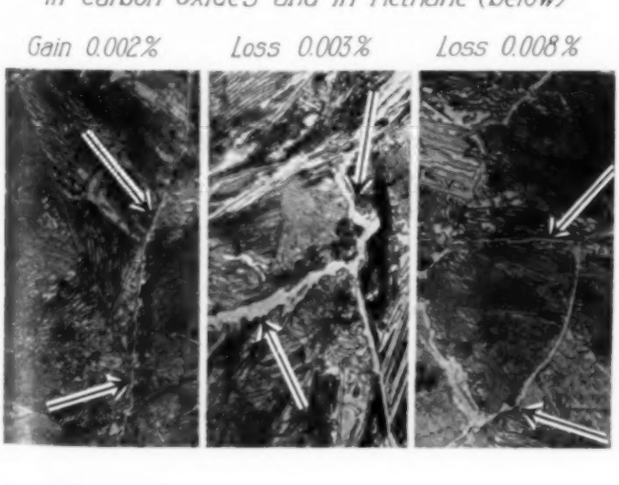
Experiments were thereupon made using various cooling periods for the normal steel until, having increased the time to about 5,000 min., the structure at the lower left (page 35) was obtained in the normal steel. Diffusion has indeed taken place; layers of free ferrite, thin but appreciable, occur around the boundary cementite. An amount of free ferrite can be obtained roughly the same as that now showing in the normal steel by reducing the cooling time of the abnormal steel to about 1 min.

What could cause such a great difference in diffusion, 5,000 to 1? Obviously, something impedes the diffusion of the carbon in the one case. *(Continued on page 102)*



Gain 0.071% Gain 0.039% Gain 0.006%

Change in Oxygen Content After Carburizing in Carbon Oxides and in Methane (below)



Gain 0.002% Loss 0.003% Loss 0.008%

Micros of Three of the Ten Steels Studied. The one which absorbed the most oxygen (0.071%) during carburization in carbonaceous material is at the left above, then an intermediate one (0.039 %) and then the least (0.006 %) at the right. After carburizing in methane all are quite normal, the first mentioned having absorbed only 0.002 % oxygen, the middle one lost 0.003 % and the one at the right lost 0.008 %. This is distinct evidence that the degree of abnormality is proportional to the amount of oxygen absorbed in pack carburizing.

POTS 'N PANS

how metal serves « « The restaurant man

RESTAURANT KITCHENS of yesterday were rather gloomy places furnished with a varied assortment of cast iron, brass and wood. Stove blacking and brass polish were taken for granted by the help. But the kitchen of 1930, resplendent with silvery stainless metal surfaces, is "a thing of beauty and a joy forever." Order, cleanliness and simplification of the food preparation processes are developed to the highest degree, mainly by the use of metallic alloys and modern machinery.

Monel metal and 99% pure nickel share honors in popularity in such a kitchen. Monel metal, a natural alloy of $\frac{2}{3}$ nickel and $\frac{1}{3}$ copper, has the essential qualities of toughness, resistance to corrosion by steam and food acids and alkalis, ability to take and retain a permanent polish, and a low thermal conductivity. Counters, cooks' tables, dish tables and service plate warmers of this material are kept bright and clean by wiping with soap and water; no laborious scrubbing with scouring powder or rubbing with polishing creams is necessary. Because of its resistance to corrosion at high temperatures, it is particularly well adapted to the construction of steam tables, and ventilating hoods over stoves and soup vats.

In the Harvey restaurants in Cleveland's new Union Terminal, the cooking is done in the main kitchen and food is carried hot from this kitchen to various tearooms and lunch counters. Monel metal, because of its low heat conductivity, is an ideal metal for food carts, for this purpose.

Heavy gage monel also forms the interior cylinders of the coffee urns shown at the right of the general view of this kitchen on the opposite page. The bodies of these urns, however, are made of a heavy sheet of 99% pure nickel, which takes a dark mirror-like finish.

Pots and pans used in a large kitchen are different from those in common domestic use, where aluminum utensils are favored. Aluminum is used for steam jacketed kettles for light cooking in the bake shop, and for equipment in the dairy. While aluminum has the advantage of lightness, it is not tough enough to stand the hard wear and rough usage given it in a busy restaurant kitchen; and while it resists corrosion, it is not stainless and turns dull in service.

A few cast iron vessels may also be found in modern hotel kitchens, used for boiling salt meats and rendering animal fats. For this purpose they are excellent, since they hold a great deal of heat without scorching the fats.

With these few exceptions, cooking vessels in the Harvey restaurant are of copper, resembling somewhat the old-fashioned pots and pans of Colonial times, but with this differ-

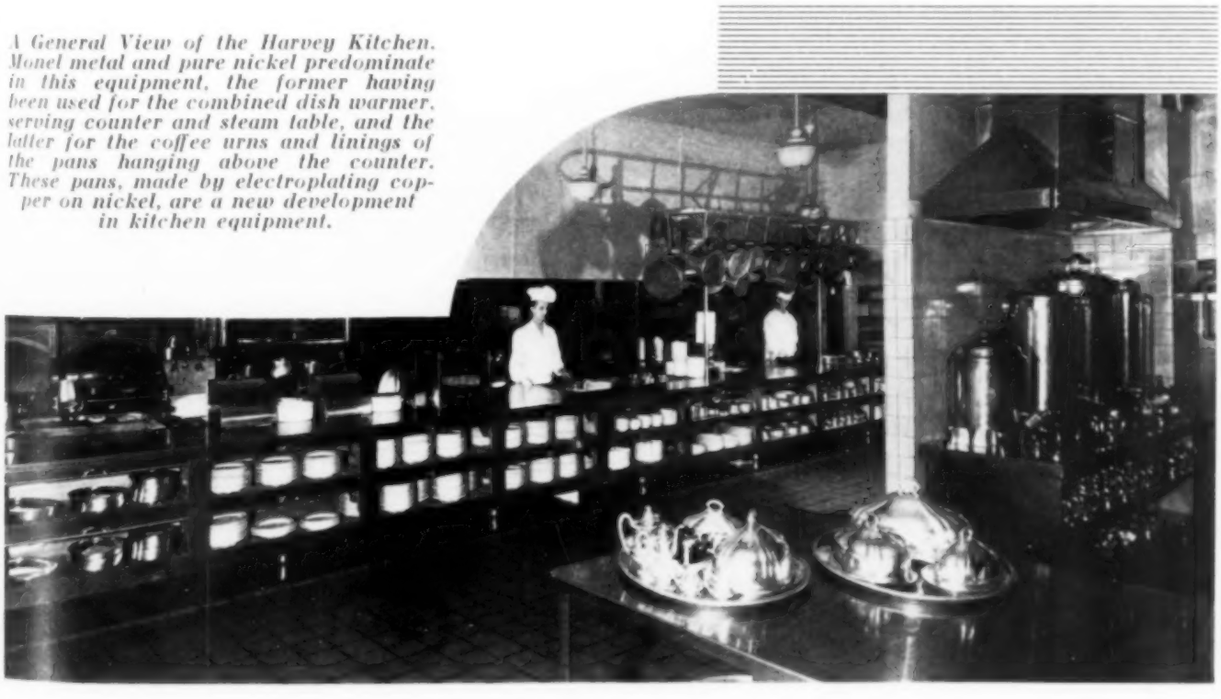
ence — they are lined with pure nickel. This gives a thick walled vessel, tough and strong; it cleans easily and does not stain. The high heat conductivity of the outer copper surface counteracts the lower conductivity of the lining. Many of the older copper pots found in restaurants are lined with tin, but it is necessary to re-tin them at frequent intervals; the nickel lining will wear indefinitely. A row of these pans hanging above the steam table is shown in the general view of the kitchen. They are of simple design, usually seamless, with rounded corners and no rims — easy to keep clean.

This same combination of copper and nickel is used in the soup vats. The kettles in the Harvey restaurant were manufactured in Austria, and it is said that only one other installation in this country owns more of them — in the kitchens which brew the well-known Campbell soup.

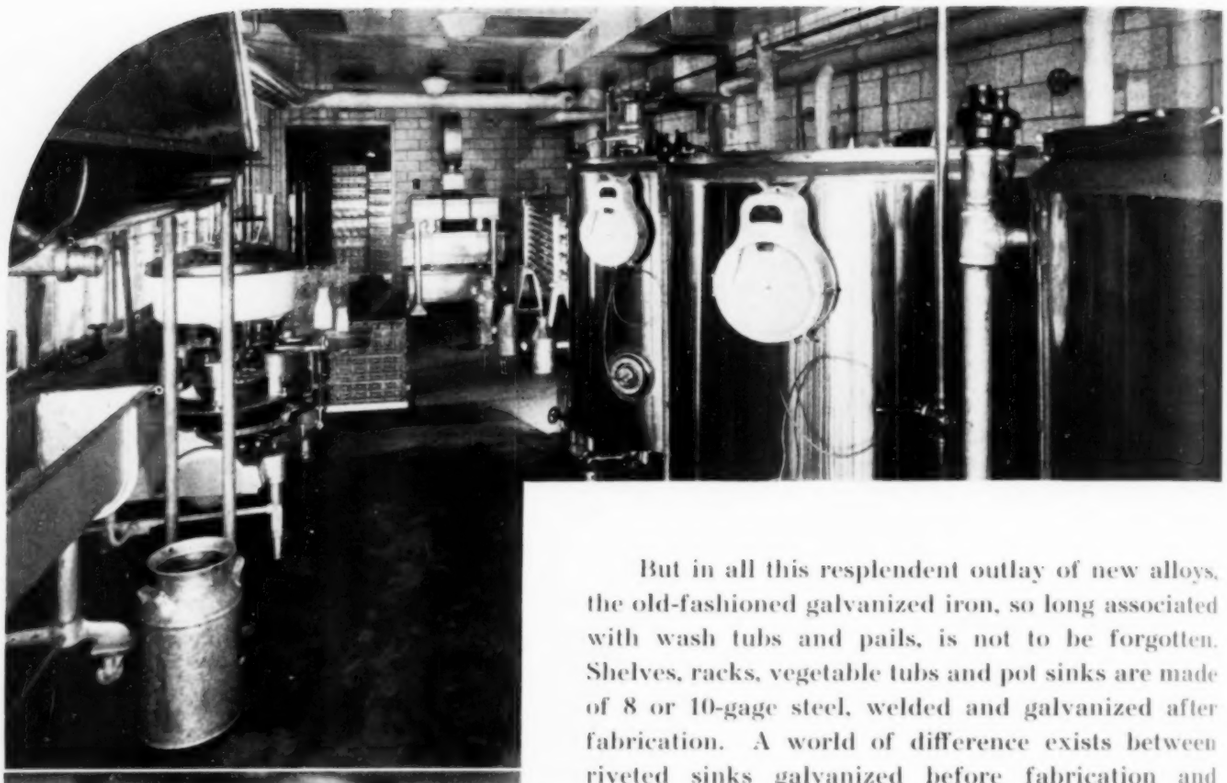
Ever since its introduction after the War, large amounts of stainless steel have been used for cutlery. Wider and more useful fields are now opened, but for kitchen knives and table knives it is still supreme. It eliminates the polishing of tarnished blades, with no sacrifice in the quality of the cutting edges.

However, the bugbear of polishing the fine silverware used in the beautiful dining room is also eliminated. The butler's main occupation, his messy preparations and old polishing rags are gone! It is only necessary to place the silver pieces in appropriate racks in the tumbling barrel, fill it with soapsuds made from specially prepared glycerine soap of high purity, close the lid, and push a button. The silver is polished by means of small steel shot and needles. The shot is made in three sizes, hand-selected, since the balls must be perfectly round in order to provide a smooth rolling friction which will remove none of the silver. The needles are necessary to clean engraved patterns and the tines of forks. No acid or reducing agent is used. Several minutes in this machine twice a week is sufficient to keep the silverware bright and lustrous.

Dishwashing drudgery is also obsolete. To assure patrons of clean dishes, one of the latest conveyor-type dishwashing machines is used. Temperature is carefully regulated so that the water is hot enough to cleanse thoroughly, without, however, cooking any egg which may happen to be on the plates. A hot water spray rinses and scalds the dishes. Here again, a monel metal installation adds to the appearance of the kitchen besides keeping the machine in a sanitary condition with the least labor. Glasses are washed in several machines, specially designed for this purpose, and located near each restaurant to avoid undue handling.



A General View of the Harvey Kitchen. Monel metal and pure nickel predominate in this equipment, the former having been used for the combined dish warmer, serving counter and steam table, and the latter for the coffee urns and linings of the pans hanging above the counter. These pans, made by electroplating copper on nickel, are a new development in kitchen equipment.



The Dairy Where Milk is Pasteurized and Bottled Without Being Touched by Human Hands Is Shown In The Top View.

Polishing Silver by Machinery. The fine steel shot which does the work is case hardened and highly polished, resembling somewhat high grade ball bearing steel.

But in all this resplendent outlay of new alloys, the old-fashioned galvanized iron, so long associated with wash tubs and pails, is not to be forgotten. Shelves, racks, vegetable tubs and pot sinks are made of 8 or 10-gage steel, welded and galvanized after fabrication. A world of difference exists between riveted sinks galvanized before fabrication and welded sinks galvanized after fabrication. The latter provide a smooth joint with no raw edges to rust, no overlapping ridges, no protruding rivets or solder where dirt and grease can accumulate. The steel is heavy enough to last almost indefinitely. This substantial material was chosen because it was considered unnecessary to use expensive alloys for service where high acid and heat resistance is not required.

Large ovens and ranges are made of cast iron and sheet steel with monel trimmings and outer surfaces. Both gas-fired and electric ovens are used for baking, electric ranges for cooking meats, and steam jacketed and pressure cookers for vegetables.

The construction of two electric ovens in the bakery is particularly interesting. Outer bodies of the ovens, with the exception of the exposed front and sides of monel, are of heavy sheet steel, lead coated on both sides to form a rust-resisting surface. Inner linings are also of sheet steel with welded joints, while individual baking chambers are provided with an aluminized finish. This reflects light from an electric bulb, which is automatically turned on when the oven door is opened. These ovens are well insulated and provided with automatic temperature control.

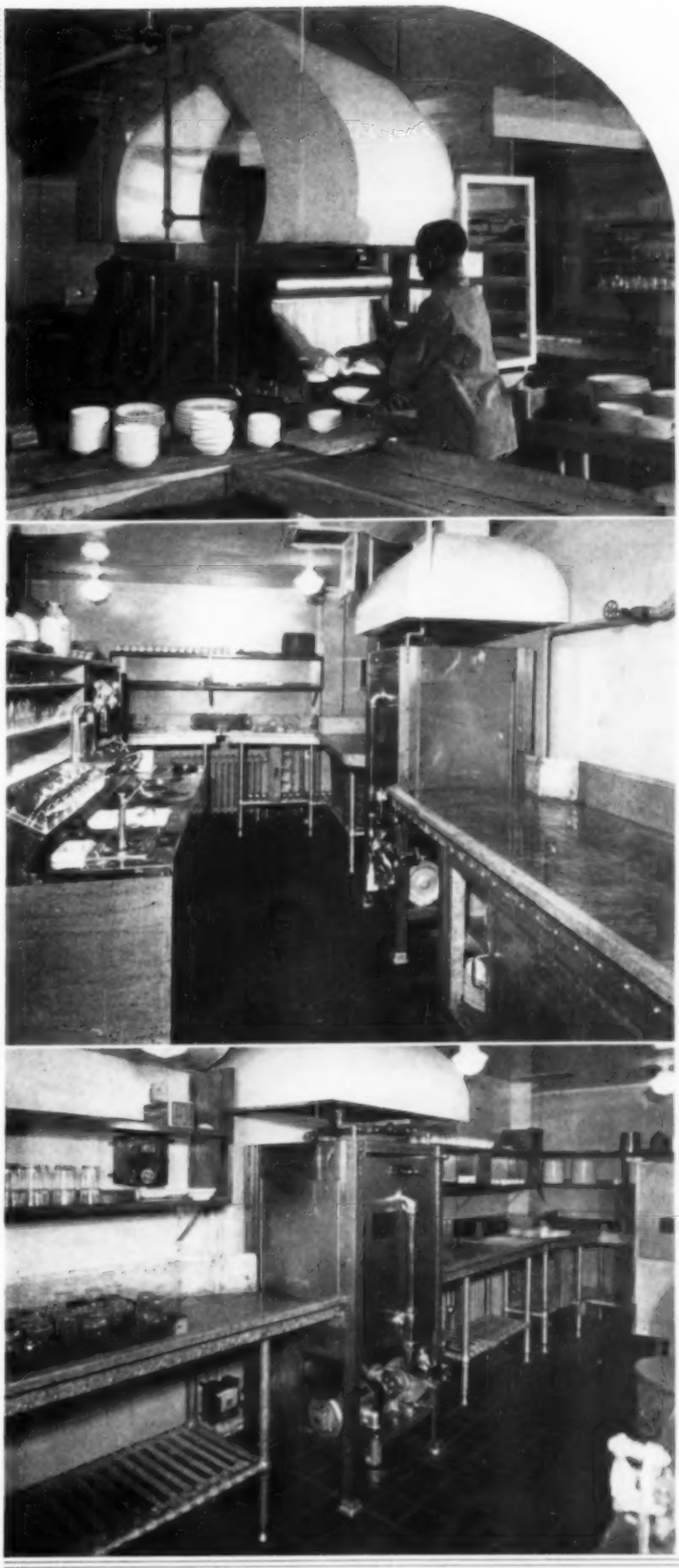
There is, however, one anachronism in the

Harvey kitchen. Alongside the latest models in electric ranges are to be found several old-fashioned charcoal broilers. The chef insists they cannot be beat for preparing thick, juicy steaks.

While the dairy is not, strictly speaking, a part of the kitchen, human hands are so completely replaced by metals that a few words about it will not be amiss.

In this department, all the milk used by the restaurant is pasteurized and all the ice cream manufactured. Pasteurizing tanks are particularly interesting. They must be kept scrupulously clean and at a constant temperature. This double requirement is best fulfilled by glass-lined tanks of nickel. Aluminum-jacketed steam kettles are also used for boiling milk and cream.

Kettles, knives, tables and cabinets; dishwashers and silver polishers; stoves, ovens and steam cookers — every corner of the modern kitchen has utilized the services of the metallurgist and the research engineer. Metal progress in the kitchen does not necessarily mean better meals than were prepared by mother on the coal range, but it does mean to the city dweller and the traveller *clean* food, food that is always uniform in quality, and food that is prepared with a minimum of disagreeable labor.



Upper View Shows a Conveyor-Type Dishwasher Made of Monel Metal. Dirty dishes, placed on the belt at one end, emerge clean and scalded, ready to be dried, at the other end.

In the Center is Shown a Glass Washer Operated in Conjunction with the Tea-room Soda Fountain; Below is a Similar Glass Washer Installed in the Kitchen.

by Christopher H. Bierbaum

HARDNESS determined by Microcut

AN instrument, known as the microcharacter, has been designed by the writer for testing the hardness of small areas and exceedingly thin sections. The procedure, briefly, consists in slowly moving with micrometer feed a highly polished and lubricated surface of the material beneath a jewel point, under a definite pressure. It is essential that this cutting point be elastically held. The width of the continuous indentation is measured at desired points and the hardness determined according to a convenient formula.

The corner of a cube was adopted as being the most desirable for a cutting point both for serviceability and also for offering the best possibility for exact duplication. Artificial leucosapphire (fused Al_2O_3) was first used because it was the hardest jewel which, up to that time, any lapidarian had been able to grind, approaching the degree of accuracy required. Unfortunately, a very slight and almost imperceptible wear of the point renders the same unfit for corroborative results. It also proved rather short-lived for many of the harder metallic compounds, and does not cut manganese and the hardest metals, neither the hardest nitrided nor the hardest chromium plated surfaces.

After fifteen years of effort and experimentation, diamond points with the required degree of accuracy have now been ground. These cutting points are made from very small, irregular stones; after the proper axis has been selected, they are ground with three facets, these three planes making a solid right angle and the point of intersection of the three planes constituting the cutting point. This was found to be without the slightest bluntness under 2000 magnifications. Its method of mounting is outlined in some detail on page 81.

The theory and procedure is quite different from that of other investigators who have resorted to so-called "scratch methods." A clean, smooth cut made by a cutting edge held in an elastic support, gives the most uniform and ac-

curate results. There should be no pulling or tearing to disturb even the smallest crystals from their natural location; that is, the vertical pressure should always be greater than the horizontal pull, a condition that obtains with the adopted cutting point. The cut should be made with the least possible ragged and torn edges; lubricating the surfaces of the test pieces with "superfine watch oil" adds very materially to the smoothness of the resulting cut. Since the degree of accuracy attained is equal to the limit of the modern microscope, the terms "microcut" and "microhardness" should be retained; also the instrument has been properly named the "microcharacter."

Precise Equipment Required

A rigid microscope in fine adjustment, one that is both delicate and responsive, is necessary; the optical system should be the very finest obtainable, especially for the study of hard metals, and possess a 1.5 mm. apochromatic objective, together with a modern filar screw micrometer eyepiece capable of making a reasonably accurate measurement of one micron.

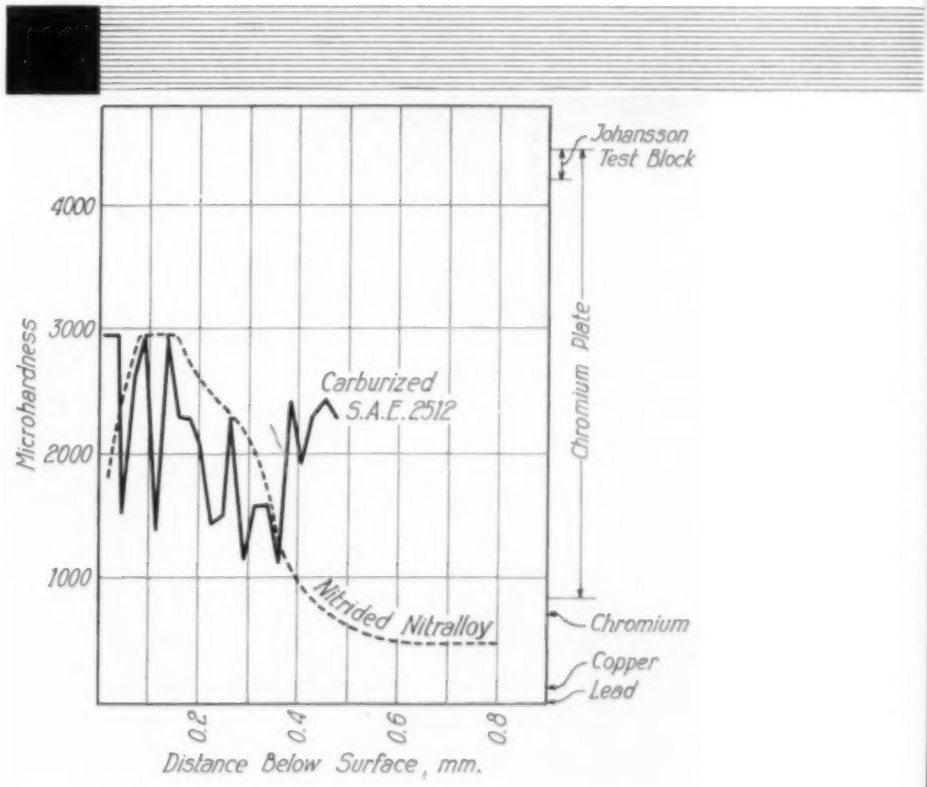
When making a test for hardness, the microscope should be accurately focused upon the test surface, disregarding the microcut. The distance between the two outer lines, representing the extreme width of metal or material disturbance, caused by the cut, should then be measured.

Sometimes it may be found that burrs or fins are formed at the edge of the cut, giving rise to confusion in the measuring of its width. It is then desirable to make a cut at right angles to the original and after careful analysis the proper reading can be determined; sometimes merely brushing a test surface at right angles to the cut with the edge of a small piece of hard wood will clarify conditions.

For general requirements, a weight of three grams on the cutting point seems to be very satisfactory and all the calculations are made on that basis, but for extremely hard surfaces a nine-gram weight offers distinct advantages. The geometry of the point is such that the width of the cut is proportional to the square of the load; therefore, after a nine-gram cut is taken, its width is measured and divided by two. With these two weights, it is possible to test the hardness of all metals varying from that of pure lead to that of nitrided steel, quenched martensite and chromium plate.

The scale of microhardness is shown in the data sheet, page 81, together with a brief explanation of its derivation. It is believed that this is the first rational scale of hardness, one that can express in definite units the relation of hardness between all the different materials, metals and non-metals alike.

Many of the alloys and purer metals show an appreciable variation of hardness depending upon the direction in which a polished surface is cut. This is a property of metals known as anisotropy, and is due entirely to the atomic orientation of the material. It is one of the con-



tributing factors why, upon a test surface, the microcut is not a mathematically straight line.

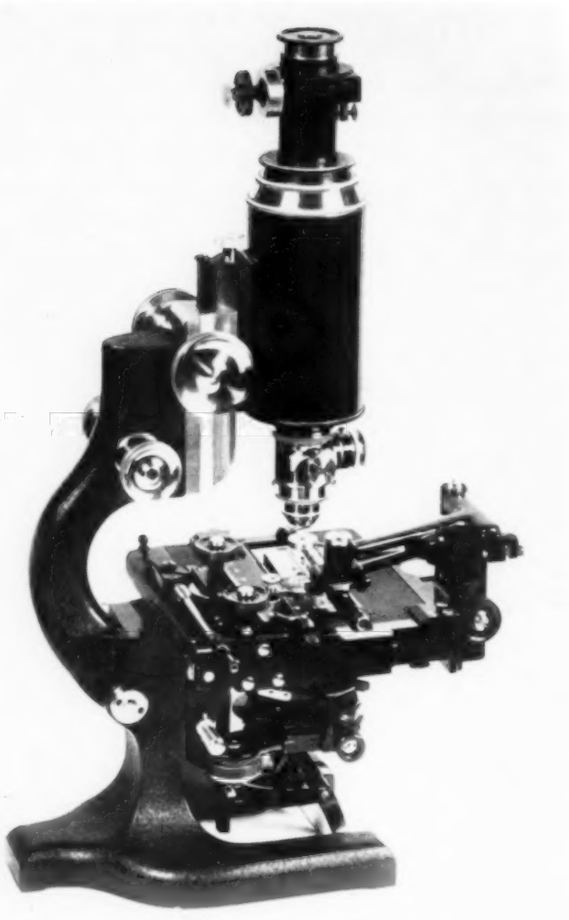
Hardness of Chromium Plate

Studies made with the diamond microcharacter indicate that the hardness of chromium plate is quite variable. A sample of metallic chromium was found to be 725 microhard. Two specimens of satisfactory electrolytic plate measured 948 and 1,900 respectively. Two others which were rough and cracked were much harder: 4,350 and 4,400. Can the hardest deposits be made without checks and unevenness?

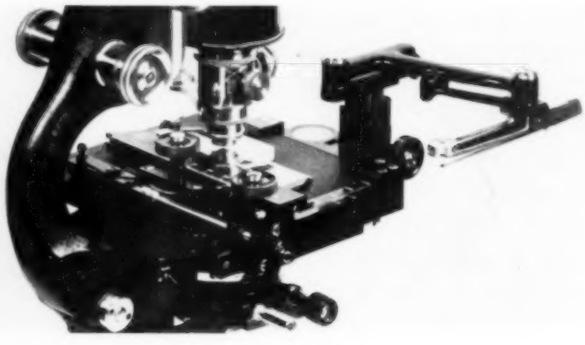
Taper ground samples of carburized and nitrided steels were also tested. The hardness readings give the true value for each depth of case, since in the softest core the penetration of the diamond is 3.7 microns (less than 0.0007 in.).

The nitrided steel tested attains its maximum microhardness (2,950) 0.08 mm. below the surface, retains that hardness to 0.16 and drops off very uniformly. A carburized sample of S.A.E. 2512 gave the same maximum, but the curve of hardness versus depth shown on page 43 has sharp peaks and valleys — the material is not uniform.

Microhardness tests were also made on an imported Johansson test block. The variations in the readings of this block are within the personal error of observation. The hardest chromium plate alone approaches or equals its hardness. The writer, in *Mining and Metallurgy*, February 1923, reported the microhardness of this block as being 2,229, whereas the present determinations indicate it to be between 4,250 and 4,430. This discrepancy is due entirely to the early use of a sapphire point, whereas the present determinations are made with a perfect diamond.



Setting of Microscope for Making Microcut. Rotation of handle at edge of stage draws polished sample past weighted diamond point. Jewel bracket is then swung aside, the surface cleaned of oil with xylol, and width of cut measured by micrometer eyepiece.



In response to a request from the standing committee on Hardness Testing of Metals, Mr. Bierbaum prepared a description of the microcharacter, invented by him, and its application to the testing of exceedingly hard surfaces. The present article is a brief summary of his paper read before the Chicago convention, A.S.S.T.

It will be printed in full in the annual volume, sent to members about Christmas.

Quality

DROP FORGINGS

require close control

DURING the last 20 years the art of drop forging has emerged from the blacksmith stage into an industry of precision and quality. This has been brought about by demands for all types of metallic shapes with a minimum tolerance and for the elimination of unsound metal, surface seams, cracks and other defects.

To understand how this advance has been achieved, a few introductory words about the methods of manufacture will be useful.

Drop forgings are produced by impact. The energy, in the form of useful work delivered by the ram to the forging, is dependent on the falling mass, its velocity and the period of time before which the downward motion is stopped.

In a gravity hammer, such as a "board drop", the available energy is equivalent to the total falling weight times the height of the fall, less friction losses. In a double-acting hammer, such as a steam hammer, the available energy is equivalent to the total falling weight times the height of that free fall which will give the corresponding velocity at impact, minus the friction.

Since the available energy in the hammer increases with the square of the velocity, it can be increased to a very high value, were it not that the metal must flow rather than be destroyed. To illustrate, a 5,000-lb. steam hammer, with an impact velocity of 34.4 ft. per sec., has approximately 91,800 ft-lb. available energy. The same energy in a 50-lb. ram would require an impact velocity of 344 ft. per sec., and the ram would be stopped in such a short time that the hot metal would be destroyed rather than worked by plastic flow.

The stresses set up in the hammer structure vary with each blow, because the greater the flow of metal per blow, the less will be the stress in the hammer. Every part of a hammer is a working member; it is, in fact, an excellent fatigue testing machine!

When drop hammers were first built, forging tolerances were generous. Rigid alignment of

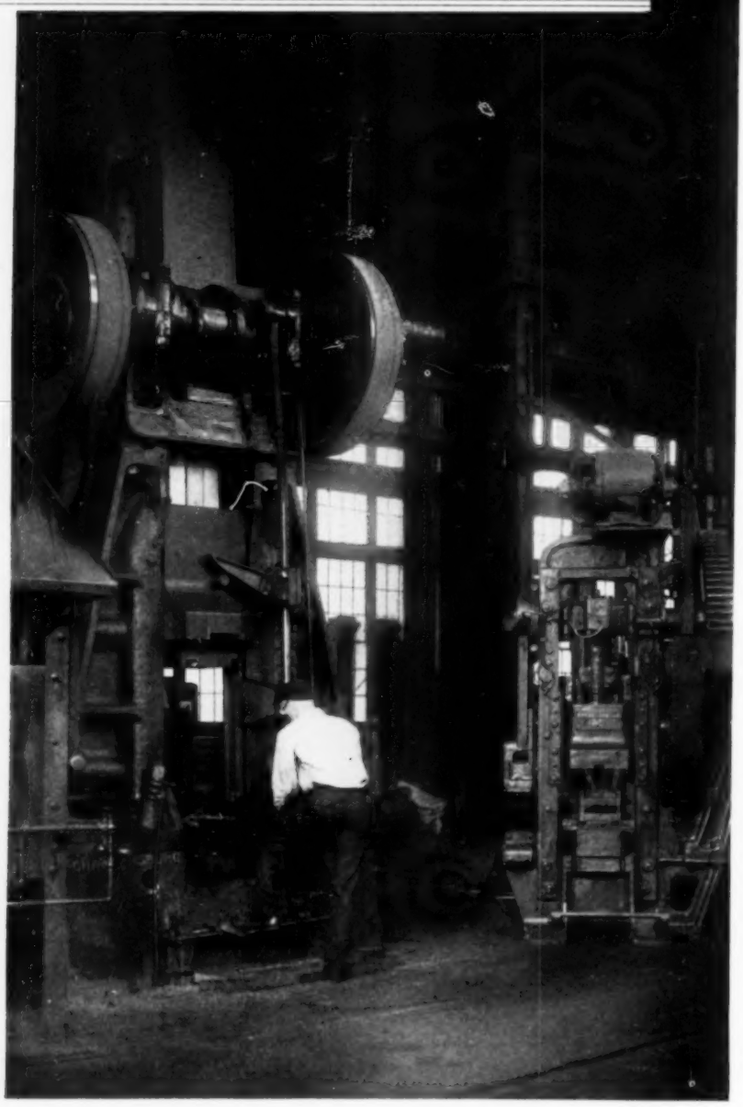
By
Adam M. Steever

the parts of the hammers was not essential; indeed a certain amount of flexibility relieved the shock from the blows. Reducing the size limits in the forgings naturally tightened the construction and imposed tremendous stresses in the hammer parts. These facts indicate that the hammer builders have had their troubles.

Cast iron, used in the early hammers, is not a material for a vibrating machine. Failures also occurred in highly stressed bolts, rods and levers, usually made of iron or machine steel. Some rams were made of cast steel, some of iron; they would break. It was not unusual to have one-quarter of the hammers out for repairs at one time.

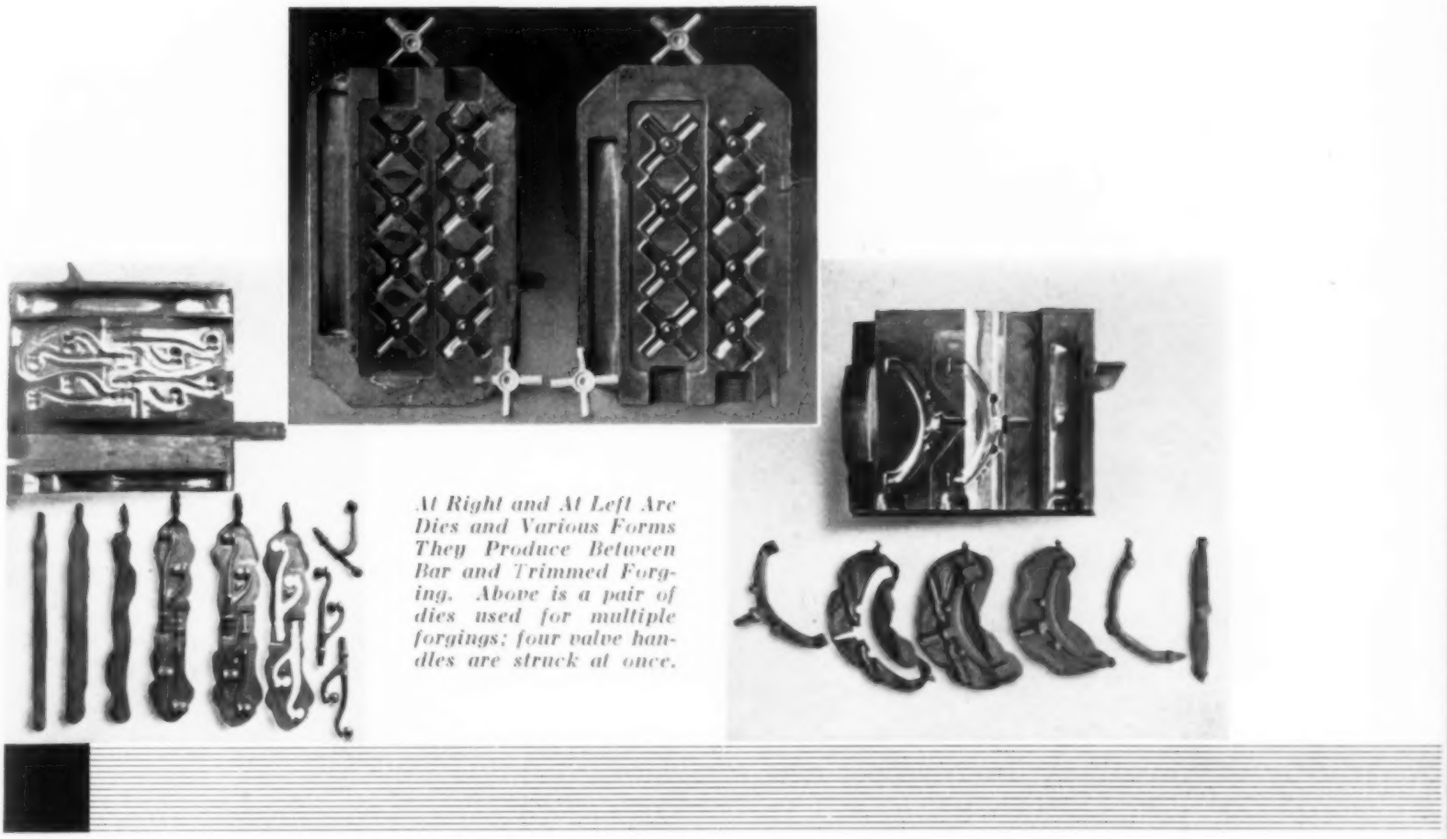
Metallurgy came to the rescue. Columns, anvils and heads are now made of steel castings. All highly stressed bolts, rods and levers are made of heat treated alloy steel. Small rams are made of heat treated steel forgings; the larger ones are cast from high grade steel. Fillets and radii of proper size on all details and the elimination of tool marks on finished surfaces have improved the life of the parts considerably. The result is that today we have a much improved hammer, as far as its materials of construction are concerned.

LET US SEE how a close specification as to size will affect the design and operation of a modern hammer. To do this we will analyze a simple forging, 8 in. x 2 in. over-all, calling for a tolerance of 1/64 in. (approximately 0.0156 in.).



The normal clearance between the ram and guides is 0.006 in. The twisting action of the ram due to this clearance, if the die impression is off center, is to the clearance as the length of the forging, front to back, is to the width between guides. Therefore, if the distance between guides is 20 in., 0.0021 in. variation is probable in addition to guide clearance. There must also be some clearance between the frames and anvil to prevent the frames from "walking upward". This clearance is about 0.001 in. Another cause of variation is temperature. As forging progresses, the dies normally would increase 300° F. in temperature. This heat passes progressively through the upper die to the ram, and through the lower die to the sow, the anvil and to the frames. Due to this temperature differential each part is tending to loosen its connections with the next part; for instance, the dies expand from their dowels, the dowels loosen, and so on. The total of these variations due to temperature accounts for another 0.001 in.

Adding together all the expected errors due to play in the hammer gives 0.0104 in., leaving but 0.0052



At Right and At Left Are Dies and Various Forms They Produce Between Bar and Trimmed Forging. Above is a pair of dies used for multiple forgings; four valve handles are struck at once.

in. (or one-third of the originally specified tolerance) to care for variations in forging temperatures, wear of dies, normal wear in the hammer, and all other variables. This is a very small margin. The makers of hammers are improving the design of their equipment, but finished forging can be made to fine dimensions only by coin pressing or cold hammer restrike. This additional finishing operation is expensive. The purchaser of forgings seldom realizes these conditions.

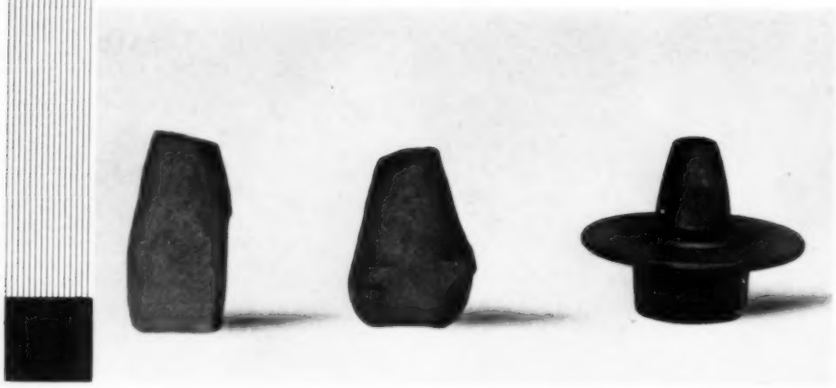
Heating the steel prior to forging is a most important step. One of the drop forger's greatest needs is to eliminate overheated and burnt steel. Furthermore, heating in the forge fire exerts a great influence, either good or bad, upon subsequent heat treatment. However, we have developed several types of furnaces with automatic temperature control which have eliminated overheating, and we find other advantages to reside in these furnaces, such as low fuel costs and long refractory life.

STEEL OF FORGING QUALITY should by all means be purchased. Customers frequently buy and inspect the steel, ordering the mill to ship direct to the drop forger — a custom which has much to commend it, especially to the smaller shops. But the problem of purchasing and inspecting forging steel is too intricate to discuss here at any length.

Proper quality of bars and billets excludes defectives from internal unsoundness, seams and surface defects. But there are other classes of defects with which the quality of billet has nothing to do. These include coldshuts, laps, dies mismatched or not properly filled, and scale pits and burnt forgings.

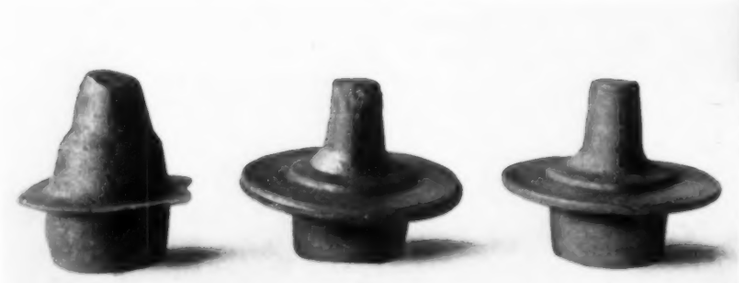
A coldshut shows up as a crack or split upon the surface. It is usually caused by insufficient stock in some portion of the impression, which causes metal to flow from other portions, and the defect is formed upon meeting. Generally it is due to improper die design or misplaced metal in the impression — the latter a fault of the hammer operator.

Laps are due to several causes, such as mismatched dies and shear cracks. Mismatched dies will cause a fin to form at the flash line and during finishing this fin is lapped into the piece. Brittle steel or improper setting of shear



Below Is a Defective Forging. Note the crack in the edge of the flange in the finished shape

Above Represents the Form Given the Metal by the Break Down Blows So That Metal Will Properly Fill the Wide Flange



knives sometimes produces a deep fracture in the bar or billet which is later worked into the forging. Alloy steel is susceptible to this defect and it is usually necessary to heat it to approximately 600° F. before shearing.

Forgings not properly filled on all dimensions are the result of improper design of the roll or rougher, of the accumulation of scale in cavities in the dies, or of insufficient stock.

Mismatched forgings are due to shifted dies, caused in turn by improper adjustment of the hammer guides, loose die keys, and worn dowels.

Scale pits are due to excessive soaking of the steel in the furnace and negligence; the hammer man should remove the scale from the piece during forging.

Burnt forgings are caused by heating the billet too hot or by blowing the air (used for descaling) on one localized part of the piece while forging.

DIE BLOCKS must absorb enormous punishment in service. They must also be made of a composition that will minimize abrasion, warping and fire cracking. Most of them are now made of open-hearth or electric-furnace steel, forged under large hydraulic presses and heat treated.

Dies are sunk in an annealed block which is later heat treated to correct hardness, when the cost of sinking in hardened steel would be prohibitive. However, the majority of blocks are heat treated by the steel maker to a 5-point scleroscope range somewhere between 45 and 58 hard. Alloy die blocks used at the Great Lakes Forge plant correspond to those described in National Metals Handbook, page 116. Heat treatment specifications are also given on page 118.

Alloy steel blocks will produce three times the number of forgings per sinking as the ordinary carbon steel block. Of course, there are many other factors that govern the life of a die impression, such as temperature of the metal being forged, type of forging steel, size of hammer and manufacturing tolerance.

Considerable study must be given to the forging before designing dies for it. Proper grain flow must be maintained in the finished production. Reduction of the material must be gradual to prevent internal ruptures. Breakdown and rolls must be so designed that they will properly form the bar to fill the next impression (called the "rougher") which gives the forging its general shape. If the rougher is properly cut, the metal will flow properly and laps and coldshuts will be avoided. The last or finish impression gives accurate dimension to the forging. The relieved portion around the finished impression (usually termed the "gutter") must provide space for the excess metal or flash.

TRIMMING DIES, to remove the flash, operate either on hot or cold metal. Hot trimming dies are used to a much larger extent, and are usually mandatory on alloy steel forgings. An increase in the use of alloy steels, the desire to avoid unnecessary transportation in the forge shop to the cold trimmer, and the longer life obtained have promoted the use of hot trimming dies.

Multiple forgings are usually trimmed cold because the cooling shrinkage is so irregular, forging to forging. At times, the trimming die governs the design of the forging die. The important uses for cold trimming are on parts that are small and delicate, and on short runs.

We use ordinary carbon tool steel for backing hot trimming dies and then weld a hard surfacing material on the cutting edge. This method has increased the life per grind 30 times. Such dies are also economical to maintain. If a forging is improperly set in the impression, the die cutting edges are usually damaged, but instead of recutting the whole die, as was necessary with tool steel trimmers, all that is now required is to weld additional material on the fractured edge and regrind.

Welding processes for this purpose have been perfected, for either the oxyacetylene blowpipe or the electric arc, but we have found the former most successful. Technique is easily learned by a competent welder.

GRAIN FLOW in the finished forging is of vital importance. Lack of knowledge on this particular subject is surprising. The question is seldom discussed by buyers and sellers, because many engineers are not familiar with its importance.

Flow of the steel crystals between the condition existing in the ingot and in the billet follows the direction of rolling and runs parallel with its length. This grain flow or fiber in steel has frequently been compared with the grain of wood; strength, toughness and general durability depend upon the way the grain is placed. In steel, likewise, it is important to insure that as far as possible the working stresses fall parallel with the direction of flow of the material in the finished shape.

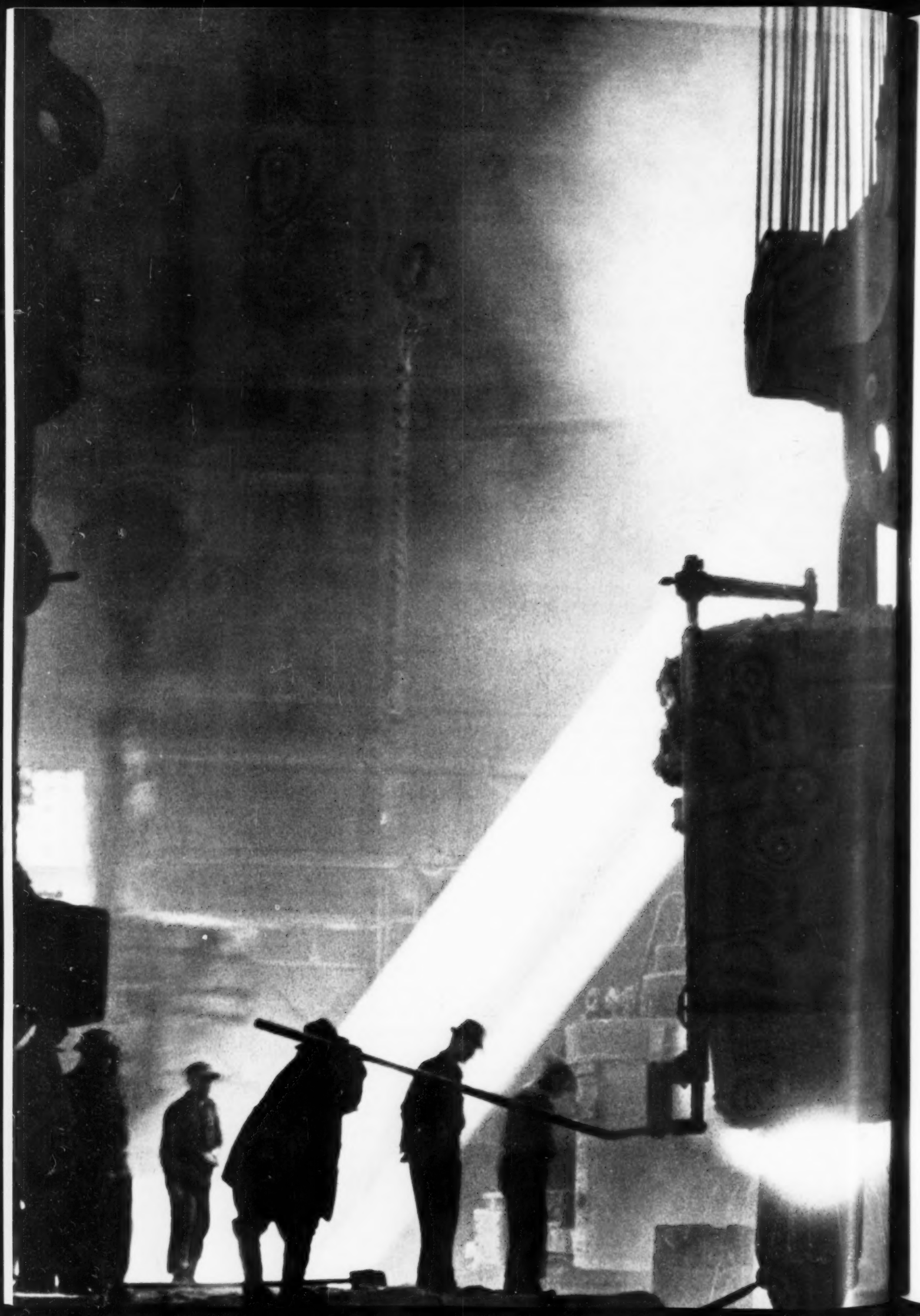
Flow lines in drop forgings possess distinctive directions depending upon the way the metal is forced into its final form. It is essential that stresses should only be allowed to fall on parts wherein the flow lines are placed in such direction as will offer the most resistance to fracture. Elimination of "cross grain" in some types of forgings requires considerable experiment and study.

Consider a gear blank, for instance. There are two methods of making this part; one by direct forging from a flat bar, and the other by hammer upsetting. The latter, which is correct, is the more costly. It produces a superior forging for the following reason:

In hammer upsetting, the slug is set on end and flattened into a disc; the disc is then placed into the impression and finished. By this method, the flow lines or grain in the original slug take up directions which are approximately radial from the center. The gear then possesses a grain which has the appearance of a spoked wheel. These flow lines run out to the end of each individual tooth, disposed properly to resist the working loads.

METALLURGICAL CONTROL is of vital importance for control of quality. Many jobs, such as steering and ball arms, gear blanks, crank shafts, are taken from the hammer during production as often as at 15 min. intervals, pickled and etched in acid and inspected to locate forging and steel defects such as laps, seams or coldshuts. If a defect of this kind is found, the job is immediately stopped and the trouble eliminated.

Before shipment, forgings should be inspected 100%. A large percentage of forgings now-a-days are also gaged for size and shape.



PIONEERING

At Midvale

ALTHOUGH industrial research is the order of the day, it is not necessary to go back much more than 20 years to find organized research in the American steel industry in its infancy. At the present time it is in full vigor, the wide recognition of its necessity having resulted in the erection of special laboratories by most of the progressive steel producers, in the formation of metallurgical sections at the Bureau of Standards, and in the establishment of such special organizations as the Battelle Memorial Institute.

It is neither easy nor especially important to separate pioneer work in metallurgy into achievements by the laboratory on the one hand (which latter usually usurps the word "research") and, on the other, those experimental steps by the operating force which have to do with the development of new processes or products. This is particularly true when close association exists between the line and the staff in taking forward steps into fields where the character of the product has undergone profound change and new methods have been devised, the changes being not chiefly dimensional. It may be of interest to review some of the work of this sort done by The Midvale Company and its predecessors.

In 1867 the establishment which was to grow into the present Midvale plant at Philadelphia was started as the William Butcher Steel Works, for the rolling into locomotive and car wheel tires of punched blooms imported from England, and for the manufacture, in crucible steel, of railway frogs and crossings. Before long, hammers were installed for punching and breaking ingots made at the plant, and for the production of hammered tool steel bars.

Chemists were rare, even non-existent, in steel works in those days, most melting being done in crucibles by mixers, using standard grades of raw materials, with which long use had made them familiar, who judged the qualities of their product wholly by the appearance of the fresh fracture. Of the chemistry of raw materials or product they knew and cared little.

In 1869 or 1870 the company acquired rights under the Siemens patents and constructed one of the first open-hearth furnaces in the United States, of 3½ tons capacity. Not much was known about the proper operation of such a furnace, which made its first heat on January 21, 1871. In the first year of its life 92 heats were cast, in truly pioneer

By John L. Cox and F. B. Foley

Photo by J. P. Mudd

work in steel, with varying degrees of success.

In 1872, almost simultaneously with its change of name to the Midvale Steel Works, there was engaged a chemist trained abroad, the late Charles A. Brinley, whose first step was to label clearly and to analyze exactly, every pile of raw material in the yard. Then began a new era in steel making, scientific control of product replacing the rule of thumb and cut and try of experience.

drop in present day specifications has been carried over from these early experiments.

In the same year the company began experimenting with ordnance steel. All previous gun work in this country had been of cast iron or bronze — almost exclusively of the former, thanks to General Rodman's methods. The first gun forgings were for 3-in. howitzers. Many experiments were made and recorded on the effects of oil and water quenching and of an-

In 1871 Captain Eads finished his famous bridge across the Mississippi at St. Louis. As is well known, it was built of chromium steel — selected by Captain Eads after he had found it impossible to get sufficient strength in the main members when made of crucible steel. The material was rolled at Midvale, which thus began the manufacture of alloy steels 57 years ago.

In 1875 a series of tests was carried out under the auspices of the Railway Master Mechanics Association at the works of John Roach, New York, to determine the relative value of wrought iron and steel axles. The steel axles were produced, as the result of many experiments, at Midvale, forged in one heat, and drop-tested under a falling ram which happened to weigh 1,640 lb. The results were a clear victory for low carbon steel, while the tests became a standard of reference. The 1,640-lb. weight of

nealing on samples of the steel, with final good success in the manufacture. This was the first work of this type done in the United States. A description of one of the first attempts at heat treating a hollow forging for ordnance has been recorded in an interesting manner by the late Guilliaem Aertsen:

"A cylindrical furnace, somewhat like the Norsemen's tower at Newport, was erected in the yard. Above its grate bars were two supporting bars on which was stood, vertically, a small gun jacket, or ring. The practice which followed was a partial imitation of hear-say description of a similar operation abroad.

"A coke fire about a foot deep was kindled on the grate bars. Other coke was brought to a state of incandescence on temporary grate bars arranged on trestles or horses on the outside of the furnace. This incandescent coke was shov-

eled in the top of the furnace with additions of unlighted coke with the idea that the whole mass could be brought to the same temperature and thus evenly heat the piece. It didn't; and the official who had started the fire at 3 a.m. with the intention of having the jacket ready to draw at 8 a.m., found himself far from the accomplishment of his purpose at that hour.

"Borrowing an idea from Biddy and the kitchen range, he filled a number of second-heat pots with 'carbon oil,' stood them around the rim of the furnace and pushed them over in the mass of burning coke.

"The result was what might have been expected and the conflagration was magnificent; but when the tube was drawn, with parts of the supporting bars sticking to it, the lower end was 'burnt' while the uper end was a 'dark cherry.'

"These were 'pyrometer readings' in 1877.

"Nevertheless, the piece was dipped and subsequently annealed and the results of the test were not uninstructive. Test bars were taken from various parts of the tube, and while parts of it were altogether wrong, some of it was pretty nearly right."

Not only was ordnance steel manufactured in the early Midvale plant, but also locomotive tires and axles and, in 1879, the steel beams and channels were rolled from rectangular billets for the superstructure of the Brooklyn Bridge.

In 1892 Midvale acquired from Messrs. Jacob Holtzer & Co. at Unieux, France, a license for the manufacture in America of the projectiles which had made that firm world-famous. The inventor of the process, Henri A. Brustlein, came to this country to inaugurate the work, bringing with him a fresh inspiration to excel in the manufacture of chromium steel, and in accurate methods of heat treatment. The Holtzer projectile was carefully annealed prior to hardening, but his experience with quenching and tempering of ordnance steels led E. S. W. Farnum to believe that the application of such treatment to the steel of the Holtzer projectile would improve its quality, and before the arrival of Mr. Brustlein he made an investigation, with results so satisfactory that these steps were thereafter made part of the regular manufacture of armor piercing projectiles of a quality unequaled at their date of manufacture.

For turning up projectiles use was originally made of tools, forged from their discard, which were distinctly superior to carbon steel tools but were inferior to certain tools, containing tungsten as well as chromium, brought over by Mr. Brustlein. Most extended researches into the characteristics of the chromium-tungsten steels were then begun and long continued.

An Old Photograph Shows the Original Research Laboratory Built in 1901 at Midvale Steel. Subsequent additions to this pioneer laboratory were made, and in it much fundamental information on ordnance and tool steels was gathered. It is soon to be superseded by the modern building shown opposite.

which early led to the adoption for use in the company's shops of a self-hardening tool steel containing about 2% chromium and 8% tungsten. For his experiments at Bethlehem, which led to the invention of the Taylor-White process of hardening high speed steels, Frederick W. Taylor, former chief engineer of the Midvale Steel Works, used steel of this type purchased from Midvale.

Later investigations into the composition and performance of self-hardening steels covered every phase of the addition of vanadium and resulted in the establishment of those proportions which to-day are in almost universal use. Similarly the effects of cobalt on high speed and magnet steels, and of tantalum, molybdenum, copper, and zirconium on steel, were the subjects of long continued research. An excellent grade of gun steel was made, high in phosphorus, at a time when phosphorus was almost universally anathematized, and many heavy forgings made of copper-bearing steels when copper was in high disfavor as an alloy for steel. Later a wide variety of compositions was made for investigation into resistance to chemical attack, and a stainless cutlery steel produced.

The investigations by James Riley into the effect of nickel on steel were eagerly followed at Midvale, which soon began the manufacture of that alloy.

The first Government specifications contemplating the use of nickel steel with which we are familiar were those for the re-engining of the armored cruiser "New York," later rechristened the "Saratoga." The tensile test figures set were the now familiar 80,000 lb. per sq.in. tensile strength, 50,000 lb. per sq.in. elastic limit and 25% elongation for annealed steel, and 95,000 lb. per sq.in. tensile strength, 65,000 lb. per sq.in. elastic limit, with 21% elongation for fully treated materials. The specifications did not directly call for the use of nickel. Since nickel was expensive and since Midvale's technicians believed it possible to reach these figures with carbon steel, the forgings were made of the latter, very successfully. Thereafter the specifications were changed so as to make obligatory the use of nickel when it was intended!

Possibly the latest development by Midvale, as the result of long and patient work, is the weldless forged steel cylinder with integral heads for large scale chemical reactions — notably oil cracking for gasoline production. Steadily, as technique could be developed, the cylinder has grown from about 36 in. inside diameter with heads bolted on, to the present 72-in. cylinder with integral flanged heads, requiring ingots weighing as much as 450,000 lb.

Early Development "Cut and Try"

Much of the development in materials and methods up to 1900 was the result of cut and try experimentation. Chemistry was firmly on its feet, but metallography and pyrometry were decidedly in their infancy. Heat treatment was based almost entirely on the results of Tchernoff's work, but with no known method for determining his A and V points beyond that of trial and error. Sorby had developed a technique for examining steel under the microscope, but the interpretation of the observed structures was uncertain and years were to pass before pioneers in England, France, Germany and America were able to develop a science of metallography. LeChatelier's thermocouple was not to become extensively used for several years, and dependence for temperature control was upon the Siemens water pyrometer, or inaccurate instruments of the type of the "Lunette Pyrometrique."

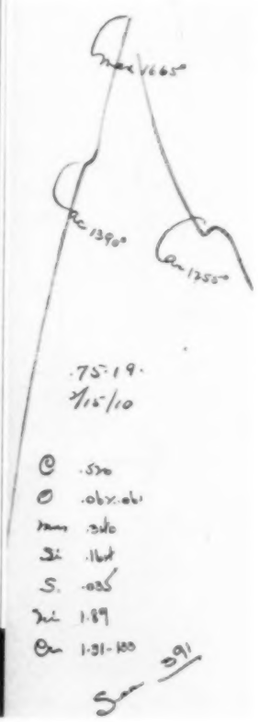
In the late 90's Sauveur started publication of his *Metallographist*. About that time, John L. Cox, who had been experimenting with the examination of steels under an inadequate student microscope in what was really the beginning of the Midvale metallographic laboratory, heard of Sauveur's work and as a result of visits to his laboratory in Boston, Midvale bought and set up a microscope equipped for vertical illumination and a Roberts-Austen critical temperature recorder.

The present laboratory of Midvale, several times extended and shortly to give way to a new and much more efficient structure, was built about 1901. As the beginning of a technical research staff, two young engineers had been sent abroad for training under Osmond, LeChatelier, Guillet and other leading specialists at the Sorbonne in Paris. If not the first, this was certainly one of the first indus-

trial metallographic research laboratories established in this country, and it was here that the experimental work was conducted which led up to the development of nickel-chromium armor at Midvale in 1901. At the same time nickel-chromium steels were further developed for use in forgings for automobiles; grades known as Midvale - Packard, Midvale - Pierce - Arrow, and Midvale - Buick were produced which now, with trifling changes in composition, appear in the standard S.A.E. series.

The need for exact temperature readings was felt at an early date. As late as 1887 the only available pyrometer was the Siemens calorimeter, a type using copper balls. Irregularities in the results attending the use of this instrument led to an investigation which developed the fact that there were two critical temperatures in the balls used, probably due to the presence of impurities in the copper, within the range of operation of the pyrometer and causing errors in its readings. Nickel proved to be free of objectionable critical points, and the substitution of nickel balls for copper eliminated these errors and added greatly to the usefulness of the instrument.

The calorimeter, and optical pyrometers of various kinds, continued to be the principal instruments for temperature measurement for many years, until the introduction of the LeChatelier thermocouple using wires of platinum and platinum-rhodium. Experience indicated that many advantages could be gained if it were possible to secure base metal couples and a sensitive yet rugged galvanometer.



Reproduction of Critical Temperature Curve, Produced Photographically in the Roberts-Austen Critical Temperature Apparatus. Its date is 1910. This equipment was later superseded by the LeChatelier-Saladin equipment. Now the Leeds & Northrup transformation apparatus is used.

In 1909, the research laboratory was made into a separate department and Radclyffe Furness placed in charge. He quickly set to work to find a uniform, reliable and accurate system of pyrometric control for the plant. Experiments were begun with base metal couples, and a Leeds & Northrup potentiometer was selected in 1911 as the most promising instrument. An early type of recording potentiometer was tested at Midvale for about a year, undergoing modification by the makers as troubles appeared, and developing finally into the well-known Leeds & Northrup recording instrument.

In the meantime the Roberts-Austen critical temperature apparatus gave place to the LeChatelier-Saladin, and, later on, the Leeds & Northrup transformation apparatus was added. The original microscope was replaced by the first LeChatelier inverted microscope. In recent years a Leitz microscope has also been installed. As new testing devices became available the equipment has been extended to take care of hardness, impact, magnetic and others forms of testing.

The new Midvale research laboratory is to be a rectangular building 50 x 100 ft. The 100-ft. dimension faces the street from which it rises two stories; from the works side it appears a three story building. The top floor is to be occupied by the chemical laboratory and is divided to provide laboratories for routine plant work, an office, special chemical research laboratories and a room for corrosion testing. The main floor is devoted to metallographic research with offices, a library and rooms for elevated temperature testing, polishing and etching, for microscope and photography. The basement, which is the ground floor entrance from the works, has a large furnace room with other rooms for pyrometry, preparation of samples for chemical analysis, storage of samples, acids and general chemicals.

by William L. Patterson

MICROSCOPES

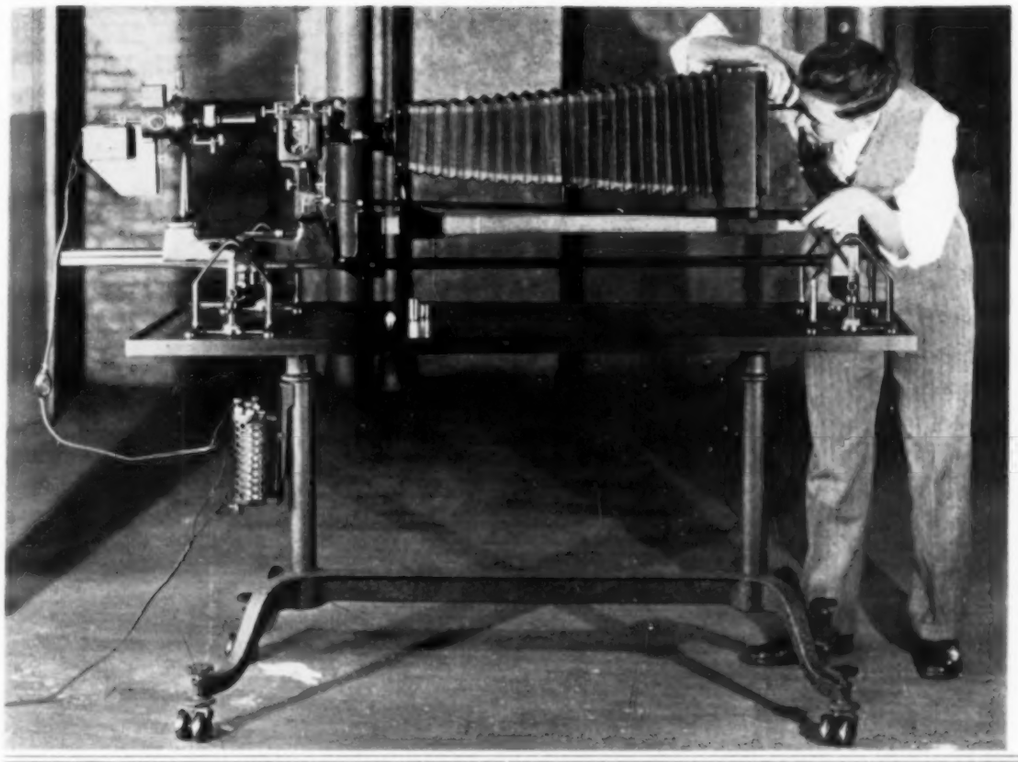
should be stable and precise

AT SOME TIME, in the first few numbers of METAL PROGRESS, it seems appropriate that a brief report should be made about the advances that have been made in the construction of metallographic microscopes during the last 10 to 15 years. If one should peruse the earlier books and catalogs and then compare their descriptions with present-day apparatus, the progress at once becomes apparent.

While the trend of the years has been toward the Le Chatelier type of instrument, it is very evident that the original models (with stage support on one side, long unsupported tubes, condensers and illuminants with all kinds of adjustments) would certainly not be adequate for present-day requirements, when the metallographer is not required to become a trained optician but must have an instrument which is immediately available for use, without tedious adjustment.

As the demand for higher magnifications became apparent (necessary for the study of recent varieties of steel), the microscope required revision. The base and column needed to be heavier and to be locked rigidly to the bed so as to become in reality one piece with the camera. The stage and its support, formerly either one-sided or an assembly of many pieces of castings, rods and bolts, needed a more rigid construction and less chance of springing or loosening.

The fine adjustment, which formerly moved the entire stage and specimen, was the greatest cause of trouble because the weight of these parts was too much for the delicate motion required. The smaller the weight the fine adjustment has to carry, the greater the possibility of



close focusing. For this reason, the present-day instruments carry only the small weight of the objective on this screw thread. The result is that in addition to being able to obtain an extremely sharp focus upon the ground glass, the instrument will not sag out of focus over a long period of time.

Another great time-saver available to the present-day metallographer is the permanent adjustment of vertical illuminator and condensers, and the fixed relation of the parts to each other, thus enabling the operator to give all of his time to the study of the metal under consideration. Cameras with bellows supports of metal are now available, thus preventing the warping and misalignment which sometimes happened in the old wooden construction.

Objectives and eyepieces now on the market are the result of many years of study by research opticians, and if the specimen is properly polished and etched, the optical system can be depended upon to bring out all the details, provided only that the correct objective as to focus and numerical aperture is selected for the particular specimen under observation.

Hours are no longer necessary to set up a metallographic outfit. Nor is it necessary to postpone photography until night, when all the machinery is stopped, since spring suspensions have dampened earth tremors to a negligible amount.

Thus has the optical industry added its mite to this time-saving age, and to the progress of the metal industry.

DIE CASTING

Zinc and Aluminum

ZINC BASE ALLOYS are made into the greatest tonnage of die castings at present. They are highly desirable to the foundry man because of their low melting point, 750° F., which temperature is not severe on the casting machine or die materials. They cast easily; the newer alloys, particularly, are very fluid and hot-tough. They may be easily plated and enameled for ornamental parts. Since their production is comparatively simple they are the cheapest of all die castings per piece.

Metallurgy of the zinc alloys is somewhat peculiar, so a short discussion will help clear up some uncertainties.

Early developments were with analyses similar to Parsons white brass, containing up to 65% tin, some copper and very little aluminum (realy a tin-base alloy). About the time of the War, several compositions were marketed under various trade names, containing copper, and aluminum often as high as 20%. Their tensile strength was approximately double that of the older alloys, and since they were not as hot-short they were much easier to cast. They met with much favor among die casters and die casting users.

It did not take long, however, for the defects of these alloys to be discovered. Many of these castings grew, swelled, warped and even cracked open. In fact, this trouble was so bad that many people still erroneously believe that any and all die castings will behave in the same manner.

A prominent zinc company led in investigating the cause of the trouble with these alloys, and the findings of Brauer, Peirce and Anderson were very illuminating. This work was preceded by Rosenhain, Archbutt, Hanson and Gayler, with work begun about 1917, but the results were first used in actual die casting practice about 1922. These various researches established certain facts concerning the zinc alloys which are now fairly generally accepted:

By
D. L. Colwell

1. Instability exists only when appreciable percentages of aluminum are present.

2. There is a triangular field of beta constituent in the equilibrium diagram which, at ordinary temperatures, breaks up into alpha plus gamma with change in volume. This volume change causes intercrystalline cracks, which, upon oxidation, cause further distortion and cracking.

3. Lead, and perhaps cadmium, accelerates this action strongly. Inasmuch as these impurities are always found in commercial zinc, it is necessary to use only the purest grade of metal obtainable.

4. Tin is also a strong accelerator. Tin is not found in commercial zinc, but since it is a constituent of the older zinc base die casting alloy, contamination with tin is not as rare an occurrence as it should be.

5. Copper, and to a certain extent, nickel, retard this phase change and therefore are highly desirable.

6. Magnesium in certain small percentages is almost an antidote. The best zinc base alloys all contain magnesium.

7. The merits of various zinc base alloys from an aging stand-

point, may be tested by prolonged immersion in an atmosphere of steam. Deterioration may be measured either by measuring the drop in physical properties, or the increase in dimension or volume.

In 1927, a group of members of the American Society for Testing Materials, now known as Committee B-6, which had already been considering aluminum die castings, extended its investigation to the problems of zinc base die castings. The table on page 100 shows the list of alloys it is investigating, and the average properties found. (Charpy impact results are for ¼-in. square pieces, not notched.) No. XVIII is the old tin-containing alloy made with so-called "Prime Western", a lower grade of zinc. No. XIV is the first aluminum-bearing alloy commercially made with high grade zinc, utilizing the findings of Brauer and Peirce. No. XV, XVI and XXI are the same alloy, with the magnesium addition, but are all included to investigate the effects of three different grades of high grade zinc. No. XIII, XVII, XIX, and XX are special alloys which are not generally used in the die casting industry, but were submitted by certain producers for test.

Chemical tests are very important, because of the peculiar effect of small amounts of impurities. Standard analytical methods and standard samples must also be established, for up to the present, good agreement has been hard to secure, even among the better industrial laboratories.

An elaborate program of aging tests is also under way. These include normal aging, accelerated steam bath aging, and accelerated paraffin bath aging. Normal aging is being conducted on specimens exposed in six out-door locations and four indoor locations. Changes in physical properties and dimensions of the test bars located at all of these points will be made at the end of one, three and five years; and at the same time, effects of corrosion will be noted.

Pending definite conclusions from this ambitious program, it may be stated that the most widely used zinc base die casting alloys of today are of two analyses. The first corresponds to A.S.T.M. No. XVIII, consisting of zinc 90.5%, copper 3.0%, tin 6.0% and aluminum 0.5%. Well made castings of this analysis are stable, but not strong, and at the present time are used

only for specific services and purposes, such as ease in soldering. The other commonly used analysis corresponds to A.S.T.M. No. XIV, XV, XVI and XXI, (3.0% Cu, 4.0 % Al, with or without magnesium) and almost invariably made of a very high grade zinc.

Because of the important effect of small amounts of impurities, it is essential that this alloy be handled properly. There are four brands of zinc on the market today of 99.97% purity or better, and two of these contain better than 99.99% zinc. It would be foolish, however, to pay a premium for such high purity zinc, and then allow the alloy to become contaminated with tin. The importance of chemical and metallurgical control from the raw materials to the finished castings, is readily apparent.

A test commonly used to appraise the stability of die castings is to immerse them in a steam bath at 95° C. for many hours continuously, and then measure the change in dimension, weight, or ultimate strength. A series of these steam tests was begun in 1922, when the effect of the steam was measured by increase in weight, and showed the necessity of using high grade zinc in the aluminum-bearing alloy. Two commercial alloys were made with low grade zinc, while two other sets of bars were made of the same alloys with the higher grade of zinc. The third pair tested was tin-bearing alloy. This latter group of four is immensely superior to the first two (made of low grade zinc) which had grown so much after a very few hours in the steam that both of them "exploded."

Another series of tests made in 1923 showed us the effect on physical properties of one year's normal aging. The tin-bearing alloy with low grade zinc showed the greatest uniformity, while the alloy made with high grade zinc carrying the most aluminum showed the greatest drop.

Drop of tensile strength after long exposure in steam was studied two years later, and determined the superiority of the alloy containing a small percentage of magnesium. This steam test was then checked by normal aging. The alloy containing magnesium showed no change in tensile strength or in elongation for two years, while the others without magnesium have shown an appreciable drop in both. This test is still going on and five-year results will soon be available.

When A.S.T.M. alloys No. XIII to XIX are exposed to steam at 160° F. for 288 hr. the im-

pact strength will be reduced to from 40% to 25% of the original value, but superiority of the magnesium-bearing alloys No. XV, XVI, and XIX over all of the others is again apparent. (All tests were made in the Charpy type machine on a ¼-in. square specimen, unnotched.)

Losses in Charpy impact strength after normal aging up to 18 months are much less. Again the superiority of the magnesium-bearing alloy is evidenced. Numbers XVI, XIX and XXI, which represent the better commercial die castings of today, show a very small loss in impact strength in 18 months. The aged specimens, averaging approximately 4, 7 and 6 ft-lb. respectively, are much higher than the other alloys, which cluster about a value of 1 ft-lb.

Specific gravity of zinc base die castings is approximately 6.6, meaning about ¼ lb. per cu.in. They can be plated easily, and can readily be machined if necessary. They are, however, rather difficult to solder, and the tin-containing alloy is the only one successfully soldered on a commercial scale. They should not be used in contact with steam or water solutions. They can be protected from aqueous corrosion, but not from aging, by the use of cadmium or some other electroplate.

For years these die castings have been used for parts carrying no particular stresses, such as automobile radiator ornaments. If these should become brittle with age no particular harm is done. Another illustration is a speedometer bracket which would be very difficult to produce economically by any other process than die casting. More recently, zinc base die castings are coming into their own as an engineering material because they can be marketed with accurate information about their performance and their permanence. It must always be borne in mind, however, that satisfactory zinc base die castings cannot be manufactured by anybody with a furnace and an air compressor, because close metallurgical control from the time raw materials are received until the finished castings are shipped, is absolutely essential for a successful product.

Aluminum Die Castings Now Popular

A more recent and perhaps a more spectacular development is the die casting of aluminum alloys. Because of the much higher temperatures involved, the engineering and production problems are much more difficult. Variations in dimension of die, of casting, and of machine parts are greater at the higher tem-

peratures; consequently the accuracy secured is not quite as great as with the metals which can be cast at lower temperatures.

Another factor which causes a great deal of trouble is the tendency of molten aluminum to attack and dissolve other metals; the problem of metal containers, therefore, is a more difficult one. Up to the present, nothing has been found more suitable than cast iron for casting-machine parts in contact with the molten aluminum. The two major difficulties with cast iron containers are the weakening of the container through loss of iron, and the contamination of the alloy by the iron dissolved.

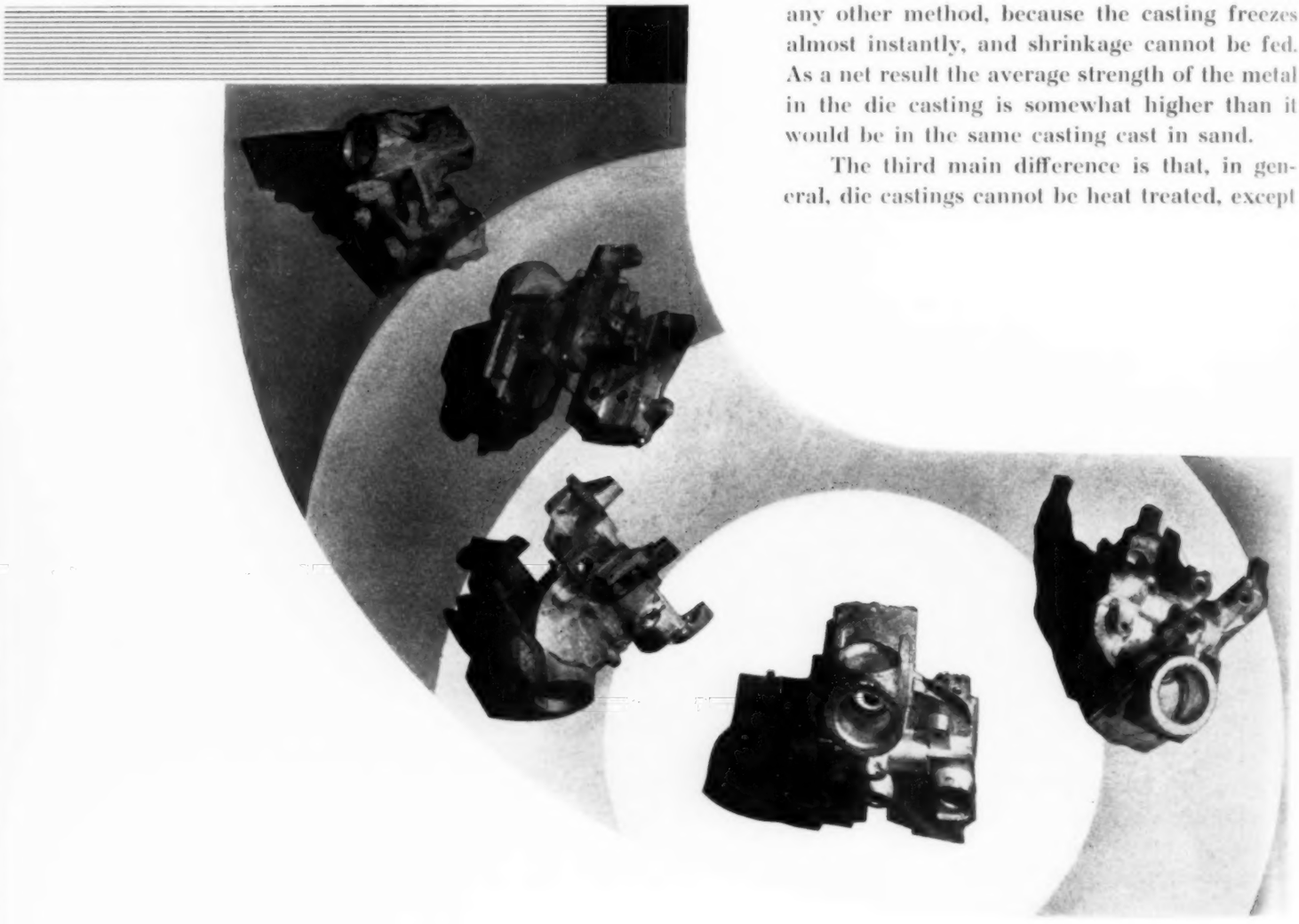
Although the tonnage of aluminum die castings is not as great, the volume compares favorably with the volume of zinc die castings. The metal cost is also about the same as the zinc alloys, when measured volume for volume. Usually, however, an aluminum die casting is somewhat more expensive, piece for piece, because the die costs more and its life is somewhat shorter.

There are three main points of difference between an aluminum alloy when die cast, and the same alloy sand cast or fabricated in some other manner.

In the first place, the aluminum die casting has, in all probability, a higher iron content, derived from its iron container. A sand casting alloy specification, for example, calling for a maximum iron content of 1% should allow a maximum of 2% iron if that alloy were to be die cast.

Secondly, an aluminum die casting is chilled more severely than is any other kind of aluminum casting. Its outer layers are finer grained, and consequently stronger. The inner layers also are more porous than when cast by any other method, because the casting freezes almost instantly, and shrinkage cannot be fed. As a net result the average strength of the metal in the die casting is somewhat higher than it would be in the same casting cast in sand.

The third main difference is that, in general, die castings cannot be heat treated, except



in rare instances. Incipient shrinkage pores under the surface and the central spongy zone contain air or gases which have been forced out of solution by the freezing of the metal. If a die casting is heated to within about 200° F. of its melting point (necessary for the solution heat treatment), the metal softens and the expanding pressure of the trapped gases causes blisters on the surface. For this reason, die cast aluminum cannot be safely heated higher than about 700° F.; for the same reason, die castings cannot very well be welded.

Aluminum die castings in some ways resemble quenched aluminum alloys. Cooling from the liquid state through the critical points takes place in the die, and is so rapid that a fine grained structure results. Silicon alloys, for instance, develop their maximum strength in sand castings only when properly "modified" to a fine grain by the use of an alkaline metal. When die cast without modification, their strength is about equal to that of the modified sand cast alloy. One would expect a certain amount of age hardening from this "quenched" structure and a very slight amount does occur in certain of the alloys.

There are three main classes of alloys used for aluminum die castings. The oldest of these is the copper-aluminum alloys containing from 3% to 16% copper. Such compositions are now giving way to the other two classes, and the copper alloys (nominally of copper and aluminum) now usually contain about 2% of silicon, and also iron, zinc and manganese, the latter usually being impurities.

Another class of alloys contains nickel, copper and silicon in varying percentages. The nickel whitens the color somewhat, and improves the polishing qualities of the casting, but also increases the cost.

Silicon alloys comprise the third class; they may or may not contain copper. They are bluer in color and lighter in weight than the other alloys, and have excellent casting properties. They do not, however, polish as well, nor are they as easy to machine. A fairly representative list of aluminum die casting alloys is given in the table on page 100, a summary of the alloys tested by Committee B-6 of the American Society for Testing Materials.

These tests are in general those made on the zinc base alloys as described above. Chemical analysis of the aluminum alloys is a comparatively simple matter; *(Cont. on page 100)*

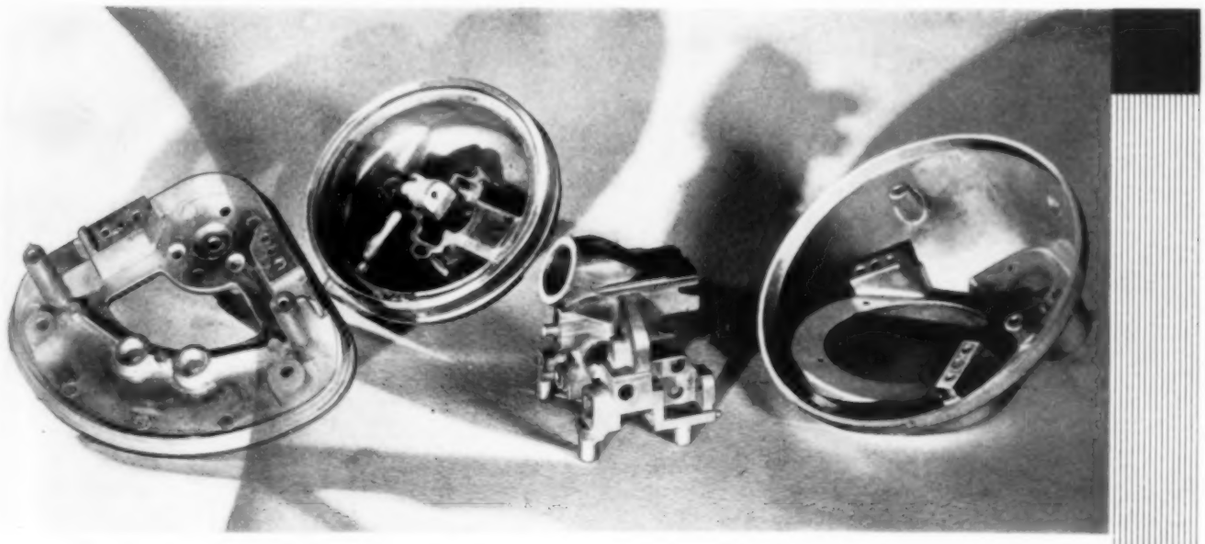


Photo by Browning Studios, New York

Editorial

MUCH CONCERN is expressed over the impending shortage of high iron ore in the Lake Districts. Less is said publicly by representatives of the United States Steel Corporation, partly from habit and also no doubt from the fact that its reserves will suffice, at the present mining rate, for 40 years. The so-called independents are in a different fix, it being estimated that within another decade they must draw their major supply of high grade blast furnace ore from other directions. An alternative, of course, is the discovery of cheap and effective processes whereby the enormous deposits of the low grade ores in the Ranges may be concentrated into material suitable for direct smelting.

Failing Iron Ore Supply

Widespread and serious industrial changes will follow the exhaustion of the Missabe iron. Three-quarters of our steel-making capacity has been located so as to enjoy cheap transportation over the Lakes. When this ore is gone, more must be secured elsewhere. Even if other American deposits can compete with foreign ore, which is doubtful, a gradual migration of the steel industry toward the new ore supplies will take place. This movement would leave behind the abandoned mining towns and smelters now so common in the Rocky Mountains, only on a swollen scale.

Of course, prodigious efforts will be made to prevent such a calamity. Even if the beginning of this dangerous age is only 10 years removed, there is still time to canvass adequately the possibility of iron-ore beneficiation, and to get used to the idea of paying something for a better smelting material.

As a matter of fact, one-third the Missabe ore now shipped is given a crude concentration process whereby some of the clay or soft gangue material is washed out. One after another of these plants have been built on the Range until there are now 37 of them. Only by judicious mixing of high grade and washed ore has it been possible to keep the iron a little over 50% in the average shipments. This figure seems to be approaching the economic limit for direct smelting. It is low enough!—55½% represented the average for Lake Superior ores 20 years ago. Only by progress in the smelting art, by using high blast temperature and low ash coke, has it been possible to counteract the steadily decreasing grade of iron ore. Obviously, there is a limit to such palliatives.

Even though mineralized areas have a way of confounding predictions and estimates of ore in place, still there is nothing any surer than that in time the present known deposits on the Ranges will be exhausted. How soon depends on many factors, but you can count on the fingers of your hands all the producing districts in the world with a history of more than a century of continuous mining. Exhaustion is as sure as death. It can only be postponed by extensive exploration for new deposits and investigation of new ore treatment methods.

Either plan has enormous possibilities, and by these means ultimate exhaustion can be postponed into the far distant future. Mineralized rock will be made into a commercial ore, either by changing its nature or by changing the smelting process. If one can trust analogies drawn from the history of other metals, the first attention will be given to the problem of making the concentrated iron ore fit for the blast furnace. A later step, possibly beyond this generation, will be to make a new reduction process to fit the concentrate.

Either of these expedients will be expensive to bring to a successful operating stage. But either will be cheaper than abandonment of the industry—to be contemplated only after all

else has failed. Likewise it won't be so expensive if the matter is taken in hand betimes. Here, as in the automobile industry, it is cheaper to spend a million a year in research and development than a hundred million every ten years in revolutionary changes, taken just in time.

ONE cannot criticize the theoretical statement that a seamless pipe or container is better than another containing a joint, no matter how well the joint is made. But like all generalizations, some qualification is necessary: "Other things being equal," such other things as uniformity in wall thickness, freedom from manufacturing defects, equivalence in chemical composition, adaptability for the purpose intended.

Joints are discontinuities, even though the joint may be a sound weld. In the present state of the art, the microstructure and composition of the material at and alongside the junction cannot help being slightly different from the metal farther away. Such variations may conceivably be the seat of future trouble, even as the best riveted or other mechanical joint may loosen or offer lodgment for corroding matter.

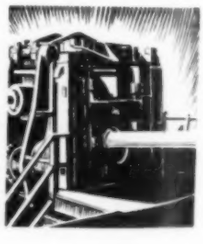
One Hundred Per Cent Welds

However, it is a mistake to assume, as most engineers are prone to do, that a weld is inherently weaker than the metal it joins. Such a statement, to be true, postulates that the composition and the structure of the plate being joined are the very best possible and cannot be improved by any means, and that no other analysis in the form of cast metal possesses greater strength and toughness.

Such assumptions are unwarranted, as any metallurgist knows. He knows that skelp and universal mill plate — the material from which welded pipe is made — while being good commercial metal, are far from uniform in their properties, either piece to piece or within a single piece. Even the best flange steel shares these defects, used as it is without subsequent heat treatment to equalize the structure imposed by the very method of rolling.

To say that the structure and properties of pipe and boiler steel, as rolled, cannot be improved, merely indicates that the speaker is ignorant of what has been done both here and abroad, where, by heat treatment, this same mild steel plate has been transformed into material of exceptionally high elastic limit and toughness. To say that rolled skelp and flange steel is the best material available, betrays further ignorance of the modern developments in alloy cast steel.

Since it is undoubtedly true, then, that skelp and plate do not represent the maximum of excellence, it is easily possible that the act of welding may actually leave the region at the junction in better physical condition than the body of the original steel. Such a transformation can be effected by a shrewd combination of heat, pressure and quenching (such as easily arranged in resistance welding machines), with scarcely any change in the chemical composition of the metal at the joint. If the full possibilities of alloying and heat treatment are utilized in fusion welding by oxyacetylene flame or electric arc, then again we see no reason why the metal at and alongside the joint may not be of higher physical properties than the best boiler plate, as it comes from the mill.



The above are not suppositious possibilities — they are commercial accomplishments. They are mentioned to refute the common but erroneous assumption that a welded joint is necessarily a source of weakness.

Unfortunately many welds are weaker than the adjoining plate, many commercial welds are porous masses of inferior cast metal, some "welds" merely stick the parts together long enough to get them out of the shop. And unfortunately the careful engineer thinks of such horrible examples when he considers and then

prohibits welding in an important structure.

But modern developments in automatic pipe welding and an accumulating body of satisfactory experience with large pressure vessels, welded by hand or machinery, will eventually convince the purchasers and operators that structures and pressure systems, welded under correct procedure control, are eminently safe and desirable. At present, it is as unfair and intemperate to say that all welds are bad as it is to say that all welds are good. Means are available for separating the good from the bad, and any user of metal fabrications who fails to use them is blinding himself to opportunities which are being grasped by his competitors.

A Good Metal Boat Beats a Wooden One

IN THE NEWSPAPERS the morning after the last race for America's cup, which was the next-fastest 30 miles ever sailed in international competition, Sir Thomas Lipton was quoted as saying, "I put their success down to the mast they have, the metal mast, and I don't blame them for having it."

Praise of metal from Sir Thomas is praise indeed!

Most of it is due to the designer of the Enterprise, W. Starling Burgess, for being such a competent metallurgist—or rather knowing so much metallurgy. A man who receives a commission to construct a cup defender is a man who is unquestionably among the leaders of his branch of engineering. Yet it is too often true that leaders in any profession are unable to appreciate the advantages of newly proposed methods or materials, since they are old enough to be a wee-bit conservative, and their reputation usually rests on former successes achieved by more conventional and standardized means. But Burgess did not play safe with the older methods of yacht construction, as did C. E. Nicholson, his British compeer. He utilized the utmost resources of modern engineering.

It is to Mr. Burgess' credit that he has been able to see where the fundamental principles of aircraft design also are applicable to the sailor's craft. It so happens that Mr. Burgess has considerable eminence in aeronautics as well as in marine architecture. Many of the mechanical "gadgets" mentioned vaguely in the news reports are merely clever devices for reducing wind resistance and eddy currents, and for aiding the crew to make sail rapidly. In their construction liberal use was made of hardened light alloys, corrosion resisting alloys, heat treated alloy steel and cold drawn high carbon steel wire. All this in addition to the steel, brass and bronze so common aboard ship.

This successful use of modern metallurgical developments in a conservative industry may well be commended to the consideration of the civil engineer who says he would put heat treated steel into his large structures if he were sure that the properties induced are permanent.

NO APOLOGY is necessary for the leading article. All who had the good fortune to listen to the Edward DeMille Campbell memorial lecture fell under the spell of Doctor Grossmann's unassuming mannerisms and witty sallies. Criticism was entirely disarmed by the clear logic with which the lecturer proceeded, step by step, to build up a proof for his main thesis. Such condensation as has been necessary to present the argument in METAL PROGRESS has been done without disturbing the author's phraseology, hoping thereby to preserve its literary charm, and to convey to the reader the pleasure of the listeners.

WELDING alloy steels improves ordnance

WELDING of really excellent quality has been developed during the last two years or three at Watertown Arsenal, Watertown, Mass. An incidental amount of such work had previously been done, of course, but it was confined mainly to maintenance work and was looked upon as a rough and ready means of making a quick repair, on an unimportant joint carrying a nominal stress. For this work a small crew of civilian welders of ordinary ability was employed. It was supposed that their output was affected by all the uncertain variables of the human equation, and consequently no one thought of proposing it seriously as an essential production process in the manufacture of field and coast defense artillery — the principal output of this arsenal. How this situation came to be changed furnishes an interesting chapter of industrial history.

Peace-Time Activities at Watertown

Naturally, operations at Watertown are in these days on a peace-time footing, and are entirely confined to the design of new types of equipment, the manufacture of enough units to prove the soundness of the innovations contained therein, and to set up definite schedules which can quickly be translated into mass production in outside plants in the event of an emergency. Such new equipment should be free from defects in the material—a failure of a weak part from overload, for instance, might throw sufficient doubt on the practicability of a new design that an innovation of real merit might be abandoned. Furthermore, artillery and ammunition must be made *right*, because a failure is likely to kill or seriously injure members of the gun crew, and in any event cause them to be very suspicious of the new material, and fail to give it a fair trial.

Procurement of sound materials is therefore an essential part of the duties of the staff at Watertown. In line with this duty, Dr. H. H. Lester, research physicist at the Arsenal, has done pioneering work with the X-ray method of inspection, and has developed this to a place where it is used among other things as an inspection tool for the control of foundry production.

Manufacture of a few mounts every year does not warrant the operation of the foundry department at Watertown, however, and the castings bought from outside vendors, when placed under the searching scrutiny of the radiograph, revealed many serious defects. Such defects as commonly observed were due to gas and sand pockets caused by loose dirt in the mold, gas pockets produced from imperfectly deoxidized metal, sand cut from the mold

or runners by the metal stream, pipes occurring under improperly functioning risers and sink heads or cavities formed by the slow flow of metal through narrow channels in the casting during final solidification of the metal.

Many of these, if not all, could have been avoided if the molding and casting conditions had been more carefully adapted to the specialized work in hand, as would have been done at the Arsenal, or if a large number of the parts had been produced. As it turned out, rejections of certain parts reached as high as 80 per cent, and delays caused by non-delivery of satisfactory castings were not only vexatious but threatened the entire developmental program.

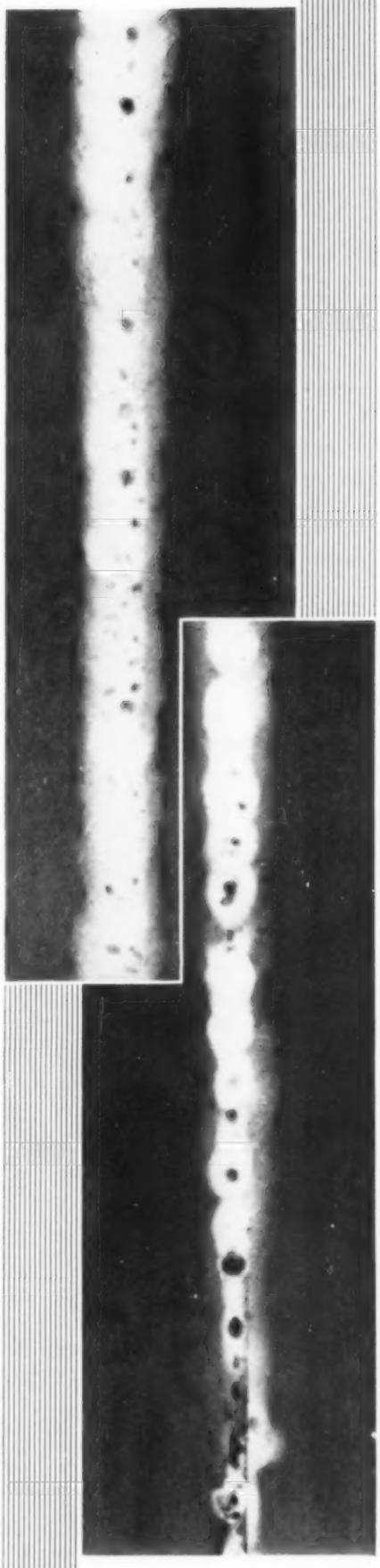
Search for Sound Material

In this emergency, the commanding officer asked his staff to investigate the possibilities of using welded assemblages of rolled steel parts as a substitute for steel castings — a movement which had already received considerable impetus in the electrical industry. It was certain that steel plate, bar, and tubing could be purchased free from the internal cavities which plagued the foundryman; the next problem was to discover whether the cast metal in the welded joints was heir to the defects of the larger castings, or was capable of attaining in routine production that high quality which is demanded of all ordnance material.

As a first step, three commercial welding organizations of good reputation were asked to make some sample welds in steel plate of the kind to be used in gun carriage construction. This was to be done, not under laboratory conditions, but was to represent the run of work which a capable workman could produce. These, when received, had an excellent external appearance, but when X-rayed, were shown to contain a very large number of internal cavities or blow holes. A selection of typical radiographs is reproduced in the column at the right.

Obviously, it would be of small avail to abandon unsound castings in favor of unsound welds, and acting on the principle that these defects could probably be prevented, the staff set about to accomplish this desirable result.

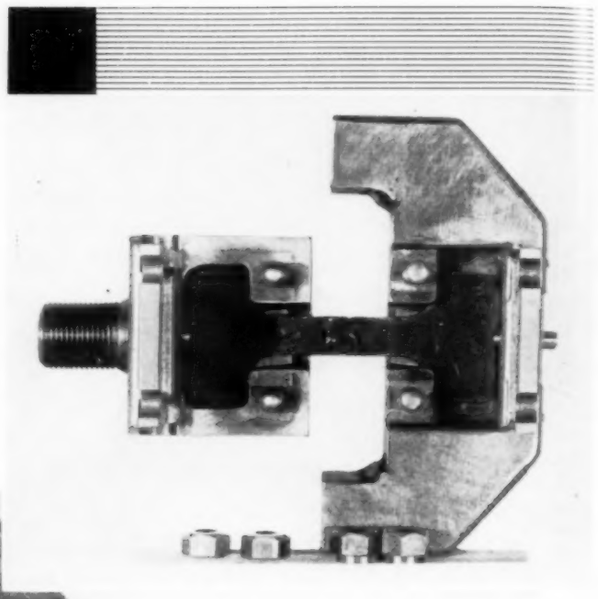
The first step was to send the foreman of the weld-

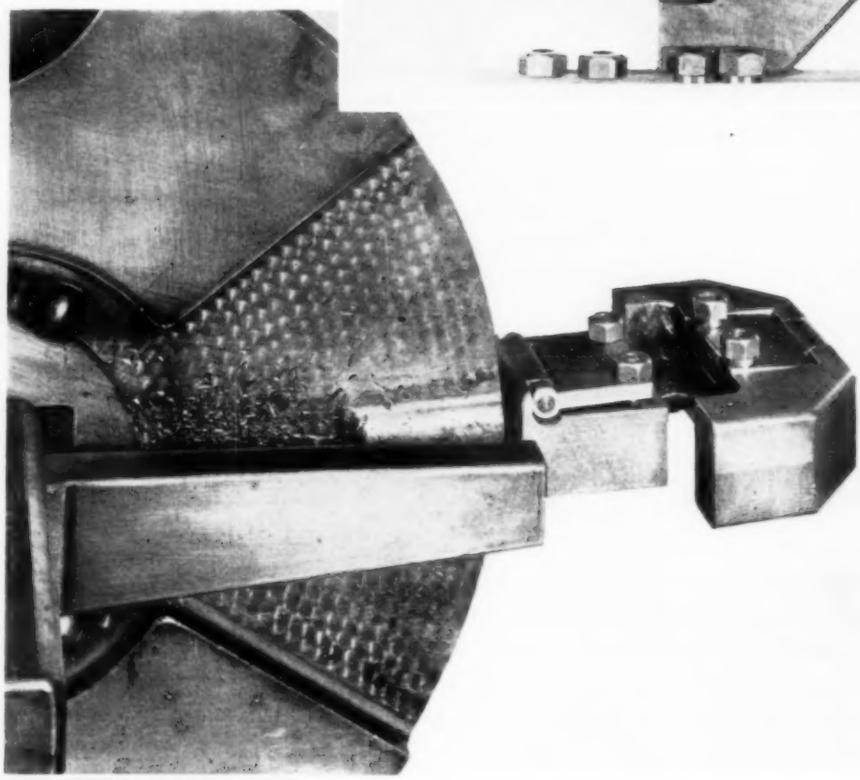


Radiographs of Commercial Arc Welds. Both appeared on visual examination to be excellent and would have been accepted by inspectors, notwithstanding the fact that one is incompletely welded on one end, and both are filled with cavities.

ing shop to Schenectady, where he spent three months in the school for welders maintained by the General Electric Co. At the end of this time he was able to pass the tests imposed by the school satisfactorily, and could make arc welds with bare metallic electrodes which would be graded "excellent" by an inspector observing the work in process and examining its appearance upon completion.

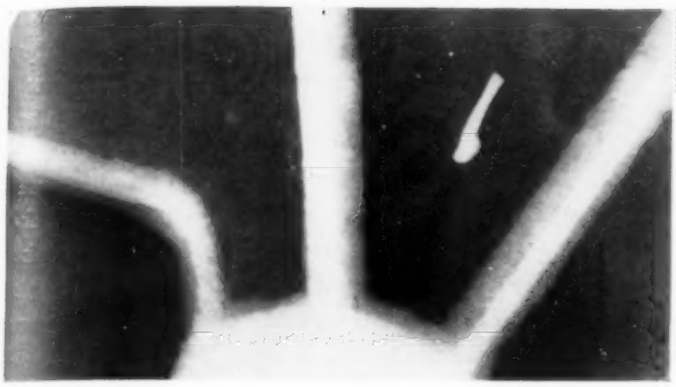
Unfortunately, the X-ray test showed the same defects that existed in those welds made in commercial production and secured some months previously for reference and study purposes.





Studies on Impact Strength of Welds in Tension. Upper view shows the test piece mounted in the special fixture (covers tilted up). Another shows the fixture closed and screwed into the hammer of the Charpy machine, in position just before striking horns affixed to the anvil. Broken test pieces below indicate a defective and a sound weld.

Not knowing the cause of these defects, apparently quite common in arc welds of commercial quality and yet inadmissible in the work on artillery mounts which was proposed, Mr. McGuire (the welding foreman) then started to vary the procedure taught him at the welding school, keeping all conditions but one as constant as possible, and varying the last one by steps through an extreme range. Each joint which passed visual inspection, and which the welder felt was sound



Sound Welds Made at Arsenal Under Production Conditions. It is a noteworthy fact that production welds are as good as, and frequently better than, welds developed in experimental laboratory.

internally, was then sent to Doctor Lester's laboratory, and an X-ray exposure made to determine the true facts.

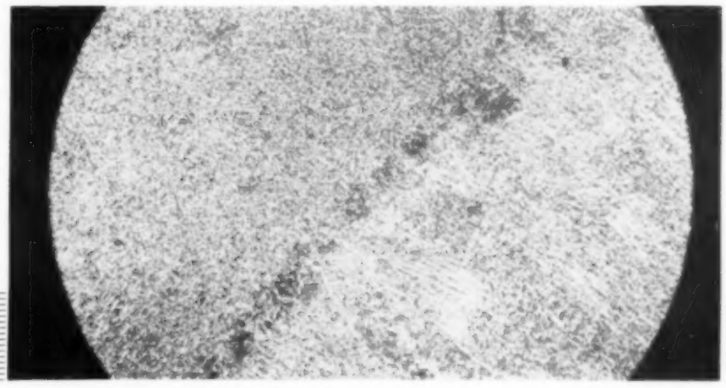
This cut and try method after several months of experimentation showed clearly that welding speeds used commonly with bare metallic electrodes are too high for sound work. Of course speeds that may be used vary with type and size of welding rod and with the nature of the plate to be welded.

In one case, when welding ¼-in. nickel steel plate with an electrode containing 0.15% carbon, it was found that a rate of 16 in. per min. with the corresponding current through the arc, gave a weld that was excellent in appearance and which would have passed ordinary visual inspection, but which under X-ray test proved to be unusually porous. Such welding speeds for this thickness of material would not be regarded as excessive by most welders. When the speed was reduced to 6 in. per min., with corresponding changes in current and potential, the blow holes disappeared entirely. Upon stepping the speed up it was found that blow holes just began to reappear at a welding speed of 10 in. per min. and this rate of feed has been adopted as standard for the jobs calling for similar material.

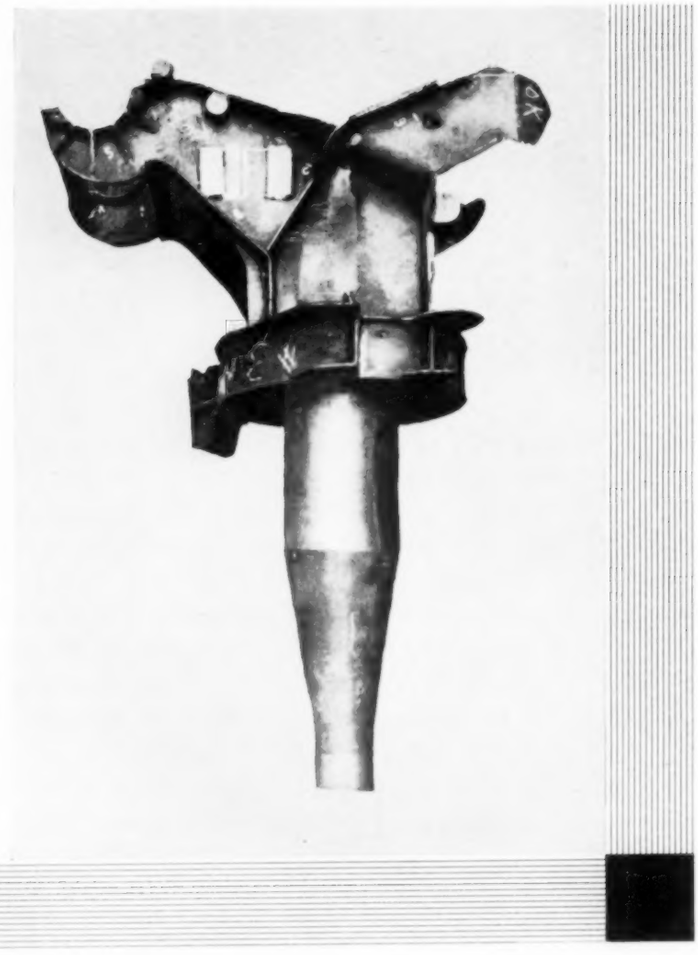
Similar investigations indicated that each welding rod (and a number of low alloy and self fluxing analyses were tried) has an optimum set of conditions which give substantially sound joints. Furthermore, that the conditions were such that any intelligent welder can conform his technique to them with a minor amount of practice, and, lastly, that there is a distinct "feel" to the operating conditions which produce sound joints, which a careful workman can recognize unmistakably. Thus, he can correct any disturbing condition as fast as it appears.

It may be argued that commercial welding cannot be done at such slow speeds, and that experience has shown that absolute soundness is unnecessary for satisfactory service. In order to get the answer to such questions physical tests were made on the sample welds to correlate the tensile and impact properties with the X-ray negatives.

Although these studies are still in progress, it early became apparent that the welds which are sound internally also have desirable



Microstructure of Sound Weld in 3% Nickel Steel Made with Low Carbon Welding Rod. Fine grained portion at upper left is weld



strength and toughness. This might have been expected by the theorist, although it is possible that electrical conditions which eliminated blowholes might have favored an extra amount of brittle nitrides or an excessive grain growth. Microstructure and Charpy impact tests show that this contingency does not exist.

To prove this point the following facts are offered in evidence:

When welding a normalized 3% nickel steel plate with a 0.15% carbon steel electrode, it is easy to build up sufficient reinforcement in the welt to cause a tensile fracture to occur in the plate rather than the joint. Such a test merely means that the joint is somewhat stronger (and stiffer) than the metal immediately adjoining it, when pulled apart by a slowly increasing load.

Much more importance is attached to the results of the Charpy impact in tension. Pieces shaped like an I are cut from the plate, across the joint, and clamped in the fixture illustrated on page 70. This fixture is screwed into the pendulum of the Charpy machine, and on its downward swing strikes the stationary horns, thus placing the specimen under a suddenly applied tension force. Fractures usually occur at or near the edge of the weld. Representative figures for joint and original metal in a specimen ½ x ⅝ x 2¼ in. gage length are as follows:

Defective weld; break at edge of joint or in the weld: 250 ft-lb.

Satisfactory weld; break outside the weld in the plate: 1400 ft-lb.

Original nickel steel plate: 1800 ft-lb.

It was found that small cracks sometimes occurred in joints made in assemblages where the adjoining metal is under constraint. If the metal is slightly undercut by the welding heat just at the edge of the welt (a condition which does not exist when making sound welds) the cracks will favor these depressions. In any event, the effect is probably due to internal stresses set up by the localized expansion and contraction of the heated metal. A series of tests indicated that approximately 90% of these internal stresses can be removed by annealing the completed part 1 hr. at 600° C., and this is now done as routine procedure at the Arsenal.

When experimental work had proceeded this far, the construction of four top carriages for 3-in. anti-aircraft guns was authorized. As shown by the photograph on this page, this is an extremely complex fixture, 19 in. overall height, and contains many reinforcing webs and brackets, both internal and external, at the trunions.

It is the very important part which carries the entire stresses from the recoil mechanism down to the mounting. It is constructed of normalized 3% nickel steel plate, with some forgings of the same material, all welded together with low carbon steel rod. All joints are welded from both sides of the plate wherever possible.

When the gun is firing in action, no part may be stressed beyond the elastic limit or ac-

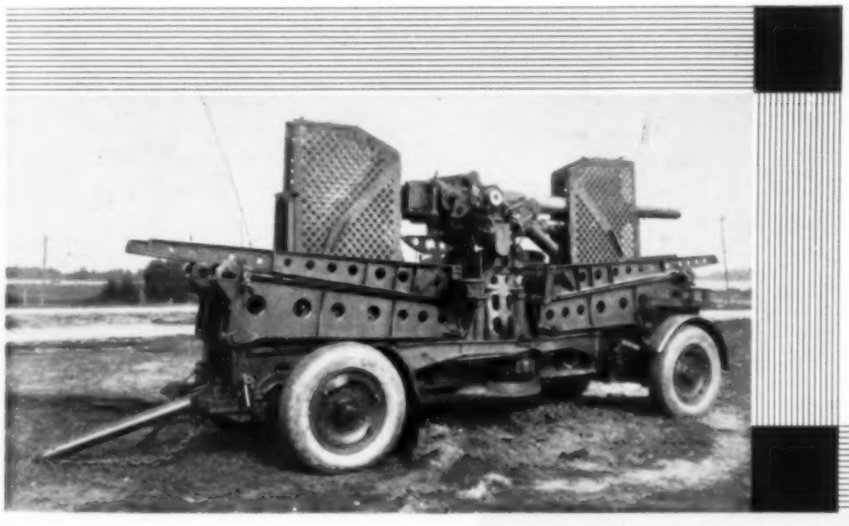
quire a permanent set, for this would cause the trunions to bind, and prevent accurate and ready pointing at the target.

These welds were given 100% X-ray inspection, and showed up fully as good as those made in the previous experimentation. The workmen were on the alert to produce a part which would be above criticism, and these carriages, which have been subjected to the most gruelling treatment at Aberdeen Proving Ground, have given entire satisfaction. This despite the fact that their weight is about half that of a corresponding steel casting.

Major J. B. Rose, who has had general charge of the welding department, recently presented a paper before the American Welding Society (*Journal*, Sept. 1929) in which he illustrates this and a number of the other parts welded by his staff. Many notable instances, seen on a recent inspection of the Arsenal, may be found on the new mobile 3-in. anti-aircraft gun, shown in the views below, and known as the Barnes gun, after Major G. M. Barnes, chief of the design section. This gun is an advanced model of the new mobile artillery, capable of transport at high speed, rapid conversion into firing position, and having automatic pointing devices for aiming at any elevation and in any direction at aircraft or rapidly moving tanks or enemy armored cars. The gun tubes are made by centrifugal casting and cold expanding as described briefly in the last issue of METAL PROGRESS.

A good premium can be paid for saving weight in such machinery. Consequently, many parts are of alloy steel or strong aluminum alloys. The gun mounting and main pedestal are of welded nickel steel plate, tubes, and forgings. Bogie axles are of welded box section.

Elevating segment is made of nickel steel web plate, side stiffeners, and a thick bar bent to a circular arc. After welding together, and annealing for stress relief, the gear teeth are cut in the outer surface of the bent bar.



Three-Inch Anti-Aircraft Gun and Mount in Travelling Position and in Action. Top carriage for this gun is shown on opposite page. It is made of 3% nickel steel rolled shapes, welded together; sound in all parts and considerably lighter than a casting serving the same purpose.

When this gun is put into action, a pair of jacks at each side of the main pedestal is run down to earth and lifts the whole structure so the wheels and axles at each end (known as the fore and aft bogies) can be disconnected and run out. Then the jacks slack off, lowering the mount to the ground. The four outriggers or trails then swing around the central pedestal until they form right angles with each other, and unfold "jack-knife fashion." The hinges lock, and give bearing on the earth at the four quadrants 16 ft. from the center of the gun mount. The perforated plates, which ride vertically, then swing down, unfold, rest on top of these outriggers, and give a firing platform entirely surrounding the gun.

Stability and Portability

This unique design and method of construction not only provides complete stability at all angles of fire, but permits the gun to be unlimbered ready for action in about 15 min., or to be folded up and be on the move again in an equally short time.

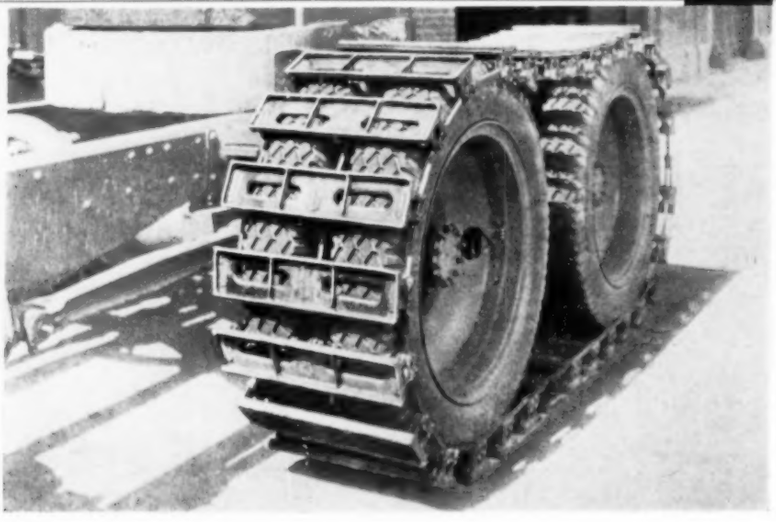
Heat treated aluminum alloy castings were used for the outriggers in the early gun mounts of this type, as well as for other fittings to reduce the weight. (The entire gun and bogies total about 8 tons.) These castings were of such large size that very few alloy foundries would be able to make them successfully, or have equipment big enough to heat treat them. In order to avoid this restriction in supply, later designs have incorporated outriggers of equal strength at equivalent deflection and weighing only a few pounds more, made of welded nickel steel plate, annealed for stress relief.

Welded and Nitrided Parts

Another interesting and valuable device recently developed at Watertown, with the aid of most modern metallurgical methods, is the demountable track illustrated below, which can be placed around the four rear wheels of the typical 6-wheel truck, whenever the load is in danger of being mired in soft ground or imbedded in sand.

The track is a series of pads, made of welded bits of nickel steel linked together with nitralloy pins into a continuous chain. The pinholes and bosses of the pads as well as the pins are nitrided to resist the wear of gritty particles inevitably finding lodgment at all rubbing surfaces. (The pads are tinned by dipping them in molten metal, and the coating machined off those surfaces which are to be hardened.)

This track is not only light and easily put on and taken off, but is unusually sturdy and will withstand more wear and rough handling than any type yet developed.



Welding, Nickel Steel, Nitralloy and Nitriding All are Used in this Demountable Track for Six-Wheel Truck

Die and Roll Steels for BRASS MILL

BRASS and copper mills, representing one of the oldest groups of metal producing industries, have always used quantities of iron and steel in the construction of their equipment. Therefore, much of the mechanical improvement which the engineer has been able to introduce into these mills has depended on the development of iron and steel of better physical properties. It would be interesting, therefore to consider, in a general way, some of the uses of these metals in this pioneer industry.

Casting Shop

In the melting of brass and copper, whether in the crucible or in the modern electric induction furnace, the molten metal has to be stirred and the dross must be skimmed off before pouring.

Stirring Rods. For this purpose, bars of wrought iron and sticks of graphite of suitable size have ordinarily been used. Wrought iron, not being fragile like graphite, was much preferred, but it was always liable to contaminate the metal by going into solution with it. This required extreme caution on the part of the melter.

Low carbon, high chromium iron has now been found to be far superior to wrought iron in this respect, reducing the danger of contamination to a minimum, but there is still a need for a material which, besides

By H. G. Keshian

being resistant to the corrosive action of brass and copper, will not become unduly brittle by repeated use.

Pyrometer Protection Tubes. There are very few things which the melter so carefully guards as the correct casting temperature of his metal. On account of interference from fumes, an optical pyrometer cannot be used, but instead a pyrometer with its fire end immersed into the pot of molten metal.

Protecting tubes made of high chromium iron will be found satisfactory when used intermittently, but for prolonged use, that is, where it is desired to leave the fire end in the furnace indefinitely, no satisfactory unfragile material for pyrometer protecting tubes has as yet come to the writer's attention.

Ingot Molds. Brass and copper are cast into molds of gray iron. Some of the melter's problems connected with these molds are identical with those of his brother melter in the steel mill. Unquestionably, in the future, both the design and manufacture of the present gray iron molds will be radically changed, and new mold metals and casting methods with services commensurate with their cost probably developed.

Rolling Mill

For scalping, overhauling and milling bars and ingots, either cast or rolled, high speed steel seems to hold its favored position by virtue of a combination of wear resistance with an undoubted ability to retain its hardness at relatively low frictional temperatures, where other types of ordinary tool steel lose their hardness and cutting edge.

Forged Gears. In the rolling of copper and brass the progressive manufacturer has not only been alert to the advantage of better methods of rolling as understood today, but also quick to adopt better materials for the various rolling mill equipment. In some instances, of course, the rate with which he has been able to buy better rolls, gears, pinions, shafts and chains has necessarily depended on the progressiveness and the readiness of the machinery manufacturers to substitute better material in the various parts of their product.

Competition here also has been playing a beneficial role to all concerned. Thus, cast iron gears and pinions are being gradually supplanted by cast or forged steel, heat treated, and soft steel shafts are being replaced by alloy steel.

Steel Rolls. Use of steel rolls for the breaking down and the finishing operations in the modern brass and copper mill is slowly but steadily gaining. Where the final cost or the ultimate economic value of steel rolls over chilled iron rolls has been established beyond doubt, their adoption has not been slow. Undoubtedly better steel rolls are now being made and the rate at which they will be introduced will quite logically depend on their relative cost and ability to prove their economic value over the chilled iron rolls.

Cold Cutters. There is no standard type of steel used for cold shearing or slitting sheet brass and copper. Among the chemical compositions to be found may be mentioned (a) plain carbon tool steel and (b) high carbon steels with tungsten or chromium. Steel for such purposes must not load up with the metal, and must also resist wear and chipping. These essential requirements for the cutters are generally controlled by the microscopic structure, the hardness and the finish which the slitters receive during the process of manufacture.

Drawbench Chains. For cold drawing equipment for making tubes, rods and shapes of various designs, iron and steel are used in different forms, such as drawbench frames, chains, carriages, dies, plugs and arbors. Heat treated alloy steel chains made of either chromium-nickel, chromium-vanadium or pearlitic manganese steels are definitely proving their superiority over the old-time medium carbon steel chains often used in natural condition.

A drawbench chain, crude as it may seem, constitutes one of the vital parts of cold drawing equipment. Manufacturers of this type of machinery have an excellent opportunity to bring this equipment to a far higher state of efficiency by applying our latest knowledge on the development of physical properties of metals, used in conjunction with definite information on the proper limits for breaking strength, yield point and elongation which the chain should possess under known conditions of operation. The user can best cooperate with the manufacturer by stating his own needs and by definitely specifying the factor of safety and the maximum pulling capacity required of the chain without apparent yield or elongation.

For drawbench grip jaws, properly heat treated plain carbon or alloy steels may be used. As these members are subject to shock as well as to a steady, straight pull, a composition having maximum toughness with reasonable hardness should be selected.

Cold Drawing Dies. Steel makers and users have a perfect understanding of the characteristics of the steel best suited for dies to cold draw copper and brass. Such steel must have the maximum wearing properties without any tendency to scratch the work. However, there is no clear agreement as to the chemical composition of that steel which will best fulfill these requirements.

Some prefer 1.00% plain carbon steel; others, steels containing from 1.10 to 1.20% carbon; still others buy a tungsten steel. Experience shows that a plain carbon steel con-

taining as low as 0.80 to 0.90% carbon will make a good drawing die.

Among the many different types of alloy steels recommended or used for drawing dies are carbon-vanadium, carbon-chromium, high carbon high chromium, low chromium high carbon, and carbon-tungsten.

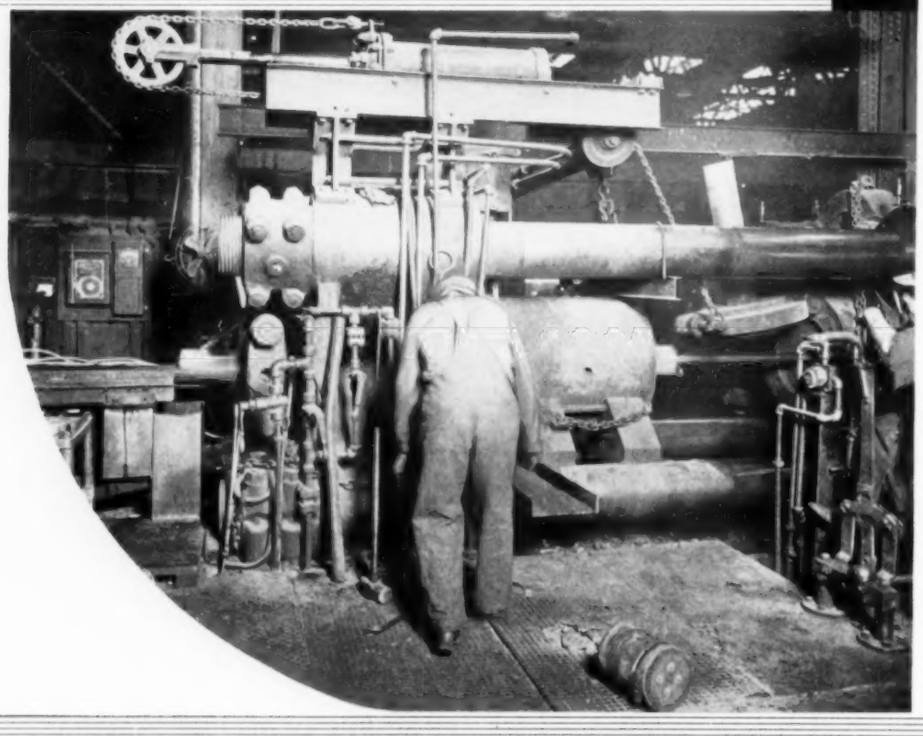
Another property which often is the determining factor in the choice of steel for drawing dies, is the readiness with which it can be shrunk back to size after the die hole has become too large. Some of the alloy steels do not shrink appreciably, and many of them shrink but slightly. It is necessary either to reforge such dies back to size or make new ones, and the schedule of operations for various draws does not always permit the shopmen to use the worn, smaller dies after reworking them to dies of larger holes.

This limited degree of shrinkability of the alloy steels is a disadvantage when they are used for drawing dies and by no means can it be overlooked. Under certain conditions, however, it will be decidedly more economical to use alloy steel dies, particularly for finishing operations.

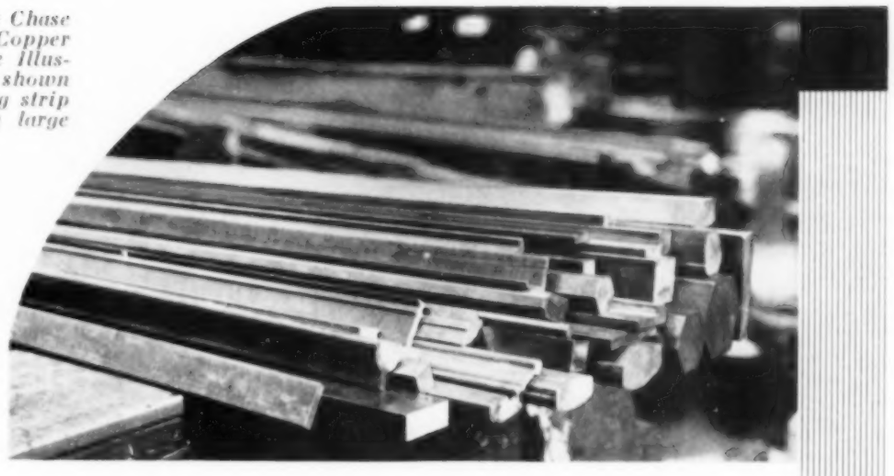
The choice of proper steel for drawing dies becomes even more difficult when other factors beside the chemical composition of the steel are to be considered. For instance, as it is well known, steels made by two different mills, even though of substantially the same analysis, as ordinarily reported by the chemical laboratory, do not always have the same quality, equal soundness, the same satisfactory microscopic and macroscopic structure or the same degree of responsiveness to heat treatment.

For drawing brass and copper wire, chilled iron, tungsten carbide, pierced diamonds, hardened steel and soft steel dies are used. Soft steel dies — usually those of alloy steels — are freer from heat checks and can be peened back to size or reforged to size. Hardened steel dies are better suited for finishing operations because they can maintain their size for a much longer period than the soft dies.

Generally speaking, alloy steels having from 1.25 to 1.35% carbon and from 4 to 5% tungsten, or 2% carbon and 5% chromium, or



Operations and Products in the Chase Company's Modern Brass and Copper Mill at Waterbury, Conn., Are Illustrated. On page 76 and 77 is shown in turn the operation of slitting strip into ordered widths, drawing large tubes on a hydraulic press, and inspecting finished small tubing. Opposite is an extrusion press; a hot billet is being inserted in the cylinder while the ram is tilted up out of the way. On the floor is a four-hole die.



2% carbon and 12% chromium give satisfactory service for the larger sizes of wire and wire rod. For relatively small wire, diamonds, tungsten carbide or wortle steel is preferred.

Steels Used For Hot Working

In hot working brass and copper, no more is expected of the steels used than for hot working iron and steel, except perhaps in the operation of extruding presses. Excluding the latter, the stresses in the rolling, piercing or forging to shape are not usually any greater than those for the similar operations for steel. Furthermore, the maximum hot working temperature for brass and copper is about 500° F. lower than for iron and steel.

General Requirements. Contrasted to this is the fact that generally the hot forged brass and copper parts require more exact dimensions and finish. This means that the dies must hold their size and shape closer and be freer from heat checks than the dies used in steel plants. Obviously for an operation of this nature a hot work steel of the best type in respect to the above mentioned requirements has to be used.

In one type of hot working encountered in brass and copper mills, namely the process of extrusion, the pressure may run as high as 80,000 lb. per sq.in., requiring a steel the essential characteristic of which must be a maximum resistance to compression or deformation at billet temperatures (varying from 1300 to 1800° F.).

In addition to these requirements of the steel used for hot working, be it forging, rolling, piercing or extrusion, there are other considerations, some of which, although not peculiar to the hot working of brass and copper, can be mentioned here. These are the rate of heat conductivity of the tool or roll, the tendency to pick up the metal or its scale, the coefficient of friction between the hot work and the steel, and the type of heat treatment that is to be used for the tool.

The latter has an economic influence. For instance: Should the tool be given a treatment at high or low temperature? Should it be cooled or oil quenched? What dimensional change occurs in the tool after hardening? Some of the steels used and intended for hot work appreciably vary in these respects and present problems which are by no means unimportant.

Types of Steel. From the standpoint of chemical composition, there seems to be no one type of steel which can be said to be best suited for all the hot working operations of a brass and copper mill. Each application has to be considered individually; the specific requirements should be clearly defined and then the steel which appears to have the necessary properties should be selected.

Hot working steels used at present can be classified as follows: (1) Those containing carbon and chromium, (2) carbon, chromium and tungsten, (3) carbon, chromium, tungsten and vanadium, (4) carbon, chromium, tungsten, vanadium and nickel, (5) carbon, chromium and molybdenum.

Hot Piercing. Among the steels used for this operation can be mentioned: A straight carbon steel having a carbon content of 0.50 to 0.60%; a carbon-chromium steel having about 0.12% carbon and about 12% chromium; a low tungsten, low carbon type of high speed steel; and a steel with 1% carbon and 4% chromium.

All of these, if properly heat treated, seem to be quite well suited for piercing machine parts coming in contact with the hot metal.

Hot Forging. Some of the steels used for hot forging brass and copper are: (1) carbon 1%, chromium 4% (2) carbon 0.30 to 0.40%, chromium 8%, tungsten 8%; (3) carbon 0.30%, chromium 3%, tungsten 10%, vanadium 0.30%; (4) carbon 0.40 to 0.50%, tungsten 13 to 14%, chromium, 3.5%, vanadium 0.50%.

Extrusion. Among the steels used for dies in the extrusion of brass and copper which have given satisfactory service in varying degrees can be mentioned the following: (1) carbon 0.30 to 0.40%, tungsten 9 to 10%, chromium 3 to 3.5%, vanadium 0.30 to 0.40%; (2) carbon 0.50 to 0.60%, with chromium, tungsten and vanadium the same as in a high tungsten type of high speed steel; (3) carbon 0.50 to 0.60%, and chromium, tungsten and vanadium the same as in the low tungsten type of high speed steel; (4) carbon 0.50 to 0.60%, and chromium, tungsten and vanadium the same as in the high tungsten high speed steel, with 7 to 8 % cobalt added.

Of the four types of steel just mentioned (2) and (3) are most generally used. As in many other applications of steel for tools, the kind of heat treatment is of much importance.

Steels used for what might be termed the secondary members of an extrusion press are those that go into the containers, liners and rams, among which the member of greatest importance as far as the problem of selecting steel is concerned, is the liner or the hollow cylinder which holds the hot billet to be extruded. There has been a gradual change in the type of steel used for these liners. They are subject to internal pressures as high as 80,000 lb. per sq.in. at temperatures running well above 1200° F.

Steels that have been used for liners are as follows: (1) chromium-nickel steels with carbon from 0.50 to 0.55%, nickel from 3.25 to 3.50%, and chromium from 1.50 to 1.75%; (2) chromium-vanadium steels with carbon from 0.60 to 0.65%, chromium from 1.75 to 2.00%, and vanadium from 0.25 to 0.30%; (3) chromium-molybdenum steel containing carbon 0.60 to 0.70%, chromium 1.75 to 2.00%, and molybdenum 0.30 to 0.40%; (4) hot work steel with carbon about 0.30%, chromium about 3%, tungsten about 9% and vanadium about 0.30%; and (5) chromium-tungsten steel.

In the fabrication of various articles from brass and copper, the kind of steel that is to be used for different operations, such as blanking, deep drawing, forming, cold stamping, clipping and knurling, needs not be especially different from that used on similar operations in fabricating steel articles. With very few exceptions, any steel that would make a satisfactory tool for the latter should also be satisfactory for the former. One of these exceptions is found in the machine shop. When turning brass a better and smoother finish can be obtained by plain carbon or by so-called fast finishing tool steels than is possible with regular high speed steel.

Typical Mechanical Properties of

WROUGHT ALUMINUM AND ALUMINUM ALLOYS

Kind of metal and temper	Tension; tensile test specimen ½-in. diameter					Nominal composition, per cent				
	Proportional limit lb. per sq. in.	Yield point lb. per sq. in.	Ultimate strength lb. per sq. in.	Yield point / Tensile strength ratio	Elongation in 2 inches per cent	Copper	Manganese	Magnesium	Silicon	Aluminum (minimum)
99.95% (O)	1,000	3,000	9,000	0.33	60					99.95
2S O	1,500	4,000	13,000	0.31	40					99.0
2S ½H	10,000	14,000	17,000	0.82	20					
2S H	14,000	21,000	24,000	0.88	10					
3S O	2,500	5,000	16,000	0.31	40					97.0
3S ½H	13,000	17,500	21,000	0.83	20		1.2			
3S H	16,000	25,500	29,000	0.88	10					
17S O	5,000	10,000	26,000	0.38	20	4.0	0.5	0.5		92.0
17S T	25,000	35,000	58,000	0.60	20					
A17S O	3,500	8,000	22,000	0.36	22	2.5		0.3		95.0
A17S T	14,500	22,000	40,000	0.55	22					
B17S O	3,500	8,000	22,000	0.36	22	3.5		0.3		94.0
B17S T	16,000	25,000	48,000	0.52	20					
C17S O	6,000	12,000	28,000	0.43	17					
C17S W	25,000	35,000	58,000	0.60	20	4.0	0.5	0.5	1.2	92.0
C17S T	32,000	50,000	65,000	0.77	12					
25S O	5,000	10,000	26,000	0.38	20					
25S W	16,000	25,000	48,000	0.52	18	4.5	0.8		0.8	92.0
25S T	25,000	35,000	58,000	0.60	20					
51S O	2,500	5,500	16,000	0.34	30					
51S W	13,000	20,000	35,000	0.57	24			0.6	1.0	96.5
51S T	18,000	35,000	48,000	0.73	14					

Kind of metal and temper	Hardness			Shear		Impact	Fatigue	
	Brinell 500 kg load	Shore Magnifier Hammer	Rockwell	Shearing strength lb. per sq. in.	Shear strength / Tensile strength ratio	Izod strength ft-lb.	Endurance limit lb. per sq. in.	Endurance limit / Tensile strength ratio
99.95% (O)	15	5	S-25	6,800	0.76	6.5		
2S O	21	7	S-23	9,600	0.74	9.0	5,000	0.38
2S ½H	32	13	E-22	11,000	0.65	10.5	7,000	0.41
2S H	38	15	E-43	13,000	0.54	10.0	8,500	0.35
3S O	28	10	S-52	11,000	0.69	11.5	7,000	0.44
3S ½H	45	16	E-51	14,000	0.67	10.0	9,500	0.45
3S H	55	23	E-68	16,000	0.55	7.5	10,500	0.36
17S O	45	15	E-54	18,000	0.69	8.0	11,000	0.42
17S T	100	30	E-96	35,000	0.60	9.5	15,000	0.26
A17S O	38	11	E-37	15,000	0.68	13.0		
A17S T	70	22	E-79	25,000	0.62	15.5	13,500	0.34
B17S O	38	11	E-37	15,000	0.68	10.5		
B17S T	80	25	E-87	29,000	0.60	12.5	15,000	0.31
C17S O	47	18	E-54					
C17S W	97	28	E-94					
C17S T	120	36	E-100	37,000	0.57	9.0	14,500	0.22
25S O	45	15	E-54	18,000	0.69	8.5	8,000	0.31
25S W	80	23	E-87	30,000	0.63	11.0	14,500	0.30
25S T	100	30	E-96	35,000	0.60	7.5	15,000	0.26
51S O	28	10	S-52	11,000	0.69	10.5	6,000	0.38
51S W	64	20	E-75	23,500	0.67	8.0	10,500	0.30
51S T	95	28	E-92	30,000	0.63	2.0	10,500	0.22

Young's modulus of elasticity is approximately 10,000,000 lb. per sq. in.

Proportional limit and yield point in compression are practically equivalent to proportional limit and yield point in tension.

O indicates annealed condition; H, hard worked; W, heated and quenched; T, heated, quenched and aged.

Yield point is taken as the stress at which the stress-strain curve shows a departure of 0.2% from the initial modulus line produced.

Prefix S to the Rockwell number indicates 60 kg on ⅛-in. ball; prefix E indicates 100 kg on ⅛-in. ball.

In the impact tests the Olsen-McAdam machine of Izod or cantilever type was used; specimen 10 mm square with notch having radius of 1 mm.

R.R. Moore type of rotating beam machine was used in the fatigue test; endurance limit based on 500,000,000 cycles.

The data were taken from Volume II "The Aluminum Industry" McGraw-Hill Book Co., 1930.

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Relation between

MICROHARDNESS AND WIDTH OF MICROCUT

for use with Bierbaum's Microcharacter

MICROHARDNESS is measured by drawing a properly ground diamond point across the polished and oiled surface. The three facets of the diamond are ground successively by turning the jewel about its axis through an angle of 120° after each grinding and at the same time maintaining its axis at an angle of 35.246° with the grinding surface. The diamond is then attached to the jewel spring in such a manner that, if the solid right angle or cutting point is considered as constituting one corner of an imaginary cube, the diagonal of this cube would then be exactly perpendicular to the test surface.

One of the edges formed by intersection of two facets forms the advance cutting edge and is in direct line with the cut. This advanced edge makes an angle of 35.25° with the test surface; this constitutes the angle of incision. The depth of cut is always slightly less than four-tenths of its width.

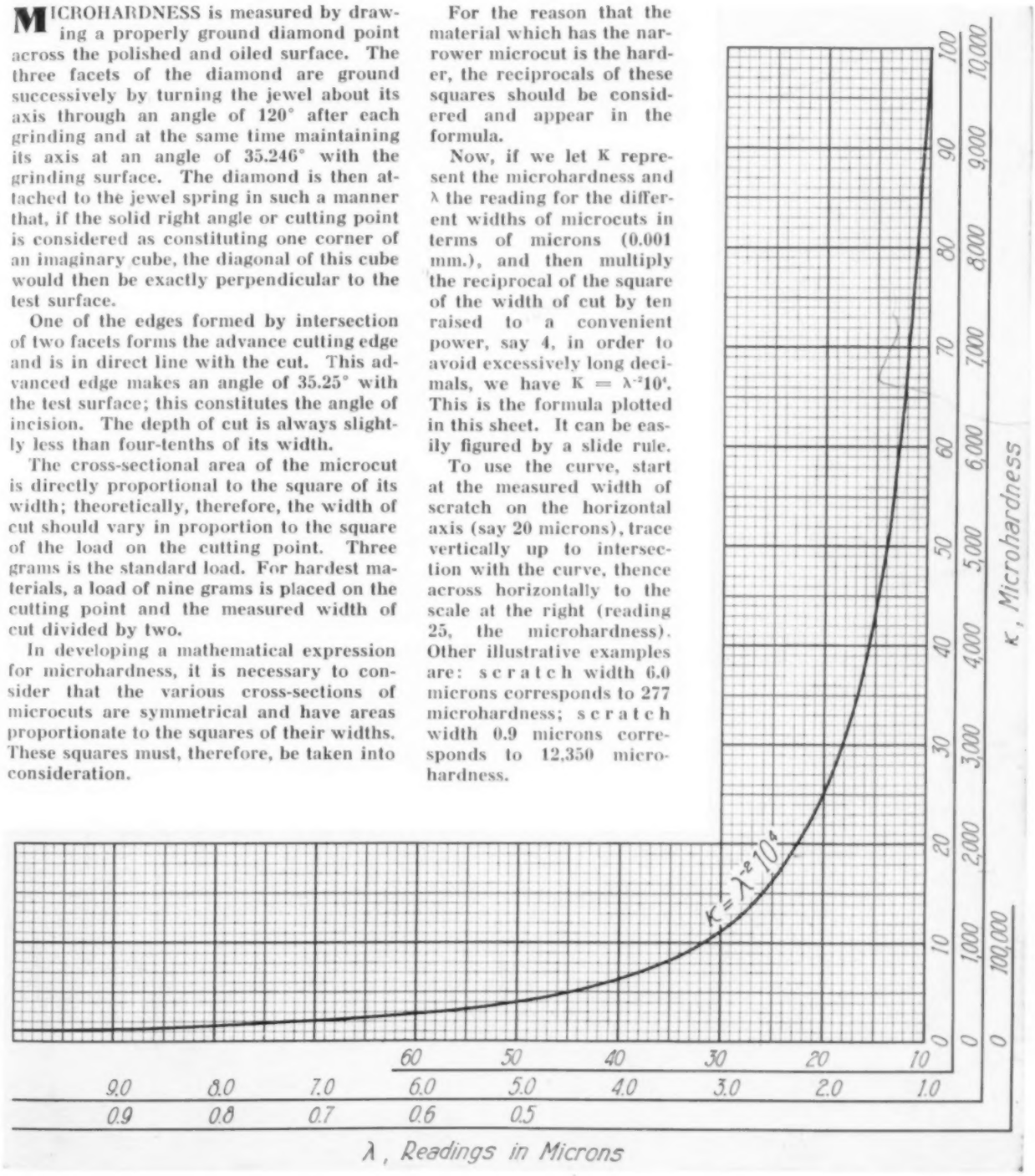
The cross-sectional area of the microcut is directly proportional to the square of its width; theoretically, therefore, the width of cut should vary in proportion to the square of the load on the cutting point. Three grams is the standard load. For hardest materials, a load of nine grams is placed on the cutting point and the measured width of cut divided by two.

In developing a mathematical expression for microhardness, it is necessary to consider that the various cross-sections of microcuts are symmetrical and have areas proportionate to the squares of their widths. These squares must, therefore, be taken into consideration.

For the reason that the material which has the narrower microcut is the harder, the reciprocals of these squares should be considered and appear in the formula.

Now, if we let K represent the microhardness and λ the reading for the different widths of microcuts in terms of microns (0.001 mm.), and then multiply the reciprocal of the square of the width of cut by ten raised to a convenient power, say 4, in order to avoid excessively long decimals, we have $K = \lambda^{-2}10^4$. This is the formula plotted in this sheet. It can be easily figured by a slide rule.

To use the curve, start at the measured width of scratch on the horizontal axis (say 20 microns), trace vertically up to intersection with the curve, thence across horizontally to the scale at the right (reading 25, the microhardness). Other illustrative examples are: scratch width 6.0 microns corresponds to 277 microhardness; scratch width 0.9 microns corresponds to 12,350 microhardness.



full--deep cups with Densite

DENSITE REFINED STEELS have certain inherent values that are not fully indicated in a static test. The large percentage of full and deep cup fractures obtained indicates homogeneity, both as to structure and inclusions, and is reflected in an increased yield point and higher ductility values. In larger sections a decided increase in toughness is more apparent.

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CORRESPONDENCE

AND FOREIGN LETTERS

High Elastic Limit Steels

A DEMAND has arisen in recent years for structural steels of higher elastic strength than the usual mild steels, especially for the more highly stressed parts of ships. Attempts have been made to meet this demand by increasing the tensile strength, either by adding more carbon or an alloying element, such as nickel. This has not been entirely successful, as the elastic limit, which is the important factor, is not always raised by increasing the tensile strength, or not to the same extent.

F. G. Martin, engineer for a leading Liverpool shipping line, pointed out in 1924 the great importance of the elastic limit (in contradistinction to the ultimate strength), and introduced a heat treated mild steel which has found considerable application in shipbuilding, and is usually known as "Martinel" steel. The elastic limit of an ordinary mild structural steel, as rolled, when determined accurately by an optical extensometer, is commonly not greater than 18,000 lb. per sq.in., while the heat treated "Martinel" steel, of only slightly higher tensile strength, gives an elastic limit of 34,000 lb.

The elastic limit, or the limit of proportionality, which is commonly assumed to be the same, bears no definite relation to the tensile strength nor the yield point, and calls for the equipment of a research laboratory for its accurate determination. It is quite a different value from that given by the "drop of the beam" of routine determination.

The first vessel in which all the important structural parts, amounting to more than half of the total weight of steel, were of such heat treated material, gave a saving of weight of 300 tons (10% of the total) as against a sister ship, constructed only of mild steel.

There are obvious objections to the necessity of special heat treatment for a mild structural steel, and similar results have been obtained in another way, namely, by altering the composition. A few years ago it was announced that a new structural steel, containing one per cent or more of silicon, had been developed in Germany. As a matter of fact, as far back as 1907, in consequence of the researches of Sir Robert Hadfield, steel with more silicon than that was used for the middle portions of the Mauretania and Lusitania, with considerable saving in weight.

There are some difficulties encountered in the manufacture of steel with high silicon, and manganese has been used in its place. The Admiralty "D" steel contains 1.1 to 1.4% of manganese with 0.33% carbon, and is required to have an elastic limit of 38,000 lb., the breaking load being 83,000 to 96,000 lb. per sq.in., and an elongation of 17% in 8 in. A bend test is also required.

A series of experiments carried out by J. A. Jones at Woolwich showed that still higher figures could be obtained without loss of ductility or impact strength by raising the percentage of both of the strengthening elements, as for instance, by using 1.3% of manganese and 0.9% of silicon with 0.30% of carbon.

The determination of the elastic limit by means of a load-strain diagram is impracticable in the works, and some other means must be adopted. The following procedure has been used in Great Britain:

Supposing an elastic limit of 38,000 lb. per sq.in. to be required, the load on the machine is made 5,000 and then increased to 38,000 lb. per sq.in. It is then lowered to 5,000 lb. The third reading must not exceed the first by more than 0.004 in., this small allowance in the 8-in. gage length being made to provide for slight eccentricity of load or other casual errors.

It is obvious that material of relatively high elastic limit has many applications to structural engineering besides those of shipbuilding.

C. H. Desch

Sheffield, England.

Italian Government Organizes Alloy Steel Manufacture

SEVERAL specific examples could be cited to prove the generalizations given in my last letter concerning the peculiar conditions surrounding the development of the Italian metallurgical industry. Perhaps the most typical would be a brief account of marketing methods used by foreign manufacturers of alloy steels and of the organization of COGNE.

Since 1890 the Italian mechanical industry has used large quantities of special steels of every description. All the leading European manufacturers had established in Italy very efficient commercial organizations for the sale of their products. In the first years of this century no less than 35 such organizations existed in Italy, and the annual sales volume of many of them far exceeded the total of 10,000,000 lire.

The well-known names of a few of these concerns will be sufficient to show the importance of this group. So I may quote from among them the following: Gebrüder Böhler, Schöller, Bleckmann, Poldihütte, Bismarckhütte, Friedrich Krupp, Röchling, Schneider, Aciéries d' Ugine, Jacob Holtzer, Chatillon-Commentry, Aciéries de Firminy, Forges et Aciéries de la Marine et Homécourt, John Brown, Thomas Firth, Brown-Bailey, Vickers, Armstrong and Edgar Allen.

Each of these concerns had offices and large stocks of special steels in the principal industrial centers of Italy. For many years competition among them for the Italian market was based on normal prices. This policy was only changed on three occasions, when certain Italian steel works — already marketing ordinary steels — tried to organize the manufacture and the sale of special steels. A keen price competition, promptly started by the powerful and well-organized importers, rapidly compelled the local manufacturers to retire from the fight. In all these occasions the "dumping" policy of the importers, practically all operating in unison, obtained a complete success.

Until 1921 or 1922, therefore, the Italian market in special steels (whose importance was rapidly increasing) was in the hands of foreign manufacturers.

Shortly after the end of the European war, the Fiat automobile company of Turin erected a large steel works, especially designed and equipped for the production of ordinary commercial steels. Its program also included the manufacture of special alloy steels for its own consumption as well as for sale on the Italian market.

But this experiment again confirmed the commercial impossibility of making high quality special steels in the same plant where large tonnages of ordinary steels are being produced. In fact, the Fiat company — though the capacity of its steel plant is at least ten times larger than its needs — still imports from abroad large quantities of special steels; while it turns out big tonnages of ordinary commercial steel shapes, of which only a very small fraction is for its own use, the balance being sold on the Italian market.

From these facts it becomes evident that the alloy steel industry in Italy was, in 1923, in exactly those peculiar conditions I have attempted to describe in my last letter, published in Metal Progress for October.

Since the experience of past years proved

that any effort to develop this basic industry in Italy would be immediately stopped by the joint competition of the foreign manufacturers, unless the new concern were favored by excellent natural conditions, such as cheap raw material of high quality, and possessed plants as large, as modern, and as highly specialized as its most powerful foreign competitors, the Italian Government decided to promote directly such an enterprise, since it was unreasonable to suppose that any other private concern, without governmental aid, could surmount the great natural and artificial barriers which exist.

Organization of the Cogne company followed this decision, which was certainly warranted by the great national importance of this special branch of metallurgy — both for the economic independence of the Italian mechanical industry, and for the national requirements in war time.

I propose to describe the plants of this new producer in my future letters to you.

FEDERICO GIOLITTI

Turin, Italy.

Space Lattice of Cementite

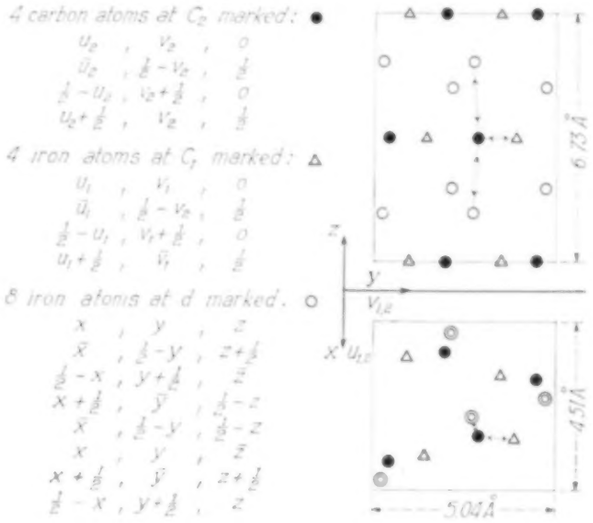
A COMPLETE determination of the space lattice of cementite (Fe_3C) has been recently made by Shigetaka Shimura, of Tokio Imperial University. Previous investigators found that its crystal structure is the same as that of spiegeleisen, and that they belong to the orthorhombic system, the number of cementite molecules in a unit cell being four. According to Shimura the dimensions of the cells, in Angstrom units, are:

Cementite: a = 4.511, b = 5.047, c = 6.738

Spiegeleisen: a = 4.504, b = 5.039, c = 6.728

The last significant figure in all instances is subject to verification.

He also found that both cementite and spiegeleisen belong to a simple orthorhombic lattice. The distribution of iron and carbon atoms in the unit cell of cementite was determined to be as shown in the sketch, with the accompanying list of ordinates.


4 carbon atoms at C2 marked:
u2 , v2 , 0
ū2 , 1/2 − v2 , 1/2
1/2 − u2 , v2 + 1/2 , 0
u2 + 1/2 , v̄2 , 1/2
4 iron atoms at C1 marked:
u1 , v1 , 0
ū1 , 1/2 − v1 , 1/2
1/2 − u1 , v1 + 1/2 , 0
u1 + 1/2 , v̄1 , 1/2
8 iron atoms at d marked:
x , y , z
x̄ , 1/2 − y , z + 1/2
1/2 − x , y + 1/2 , z̄
x + 1/2 , ȳ , 1/2 − z
x̄ , 1/2 − y , 1/2 − z
x , y , z̄
x + 1/2 , ȳ , z + 1/2
1/2 − x , y + 1/2 , z
6.73 Å
4.51 Å
5.04 Å

The parameters for iron atoms have the following values: $u_1 = 0.2050$, $v_1 = 0.1987$, $x = 0.0550$, $y = 0.4325$, $z = 0.3156$, and those for carbon: $u_2 = 0.181$, $v_2 = 0.415$.

Three iron and one carbon atoms, such as the quartet joined by arrows in the figure shown above, may be considered as forming a cementite molecule.

Other scientific studies recently completed in Japan include the determination of the solidification shrinkage of three eutectic alloys by K. Honda, Y. Matsuyama and T. Isobé. By means of a thermo-balance they determined the shrinkage of these alloys of manganese-carbon, nickel-carbon and cobalt-carbon during solidification, the results being expressed as a differential of the volume by the volume:

Mn-C eutectic alloy: − 1.60%

Ni-C eutectic alloy: + 2.06%

Co-C eutectic alloy: + 2.03%

The same change of volume in the eutectic alloy of iron and carbon varies from −3.70 to +2.74% according as the cast iron solidified contains from zero to 3.1% of graphite, these results having been obtained two years ago.

The autumn meeting of the Iron and Steel Institute of Japan will be held this year at Muroran, Hokkaido, from October 9 to 15. At the meeting 35 papers will be read, and several excursions enjoyed. A special discussion on methods of metallurgical investigation will be

held on the afternoons of October 11 and 12. Among the important papers to be presented at the meeting are:

Ash in blast furnace coke, and its relation to fuel efficiency; A by-product of the manufacture of coke; Oxidation and reduction of iron sands; On the binary system of FeO and SiO_2; Chemical reaction in the blast furnace; Heat treatment of a cast iron roll; Properties of special cast iron; Nature of white spots in steels and their prevention; Fibrous structures in steel; An investigation of nickel-copper steel; On temper brittleness; On high manganese austenitic steel; Ternary alloys of iron, nickel and chromium; Automatic recording dilatometer for quenching.

KOTARO HONDA

Sendai, Japan.

News Print Competes With Swedish Steel

BECAUSE of Sweden's well-nigh complete lack of fossil fuel deposits, the iron industry in this country must depend upon charcoal for producing nearly all its pig iron. Reduction of iron ore by means of charcoal certainly favors quality in the steel, but the consumption of this forest product has confronted the iron makers with problems which are probably unknown to their colleagues in other countries.

Our iron industry now has to compete with the sulphate pulp industry for the wood. It is either steel or paper! Furthermore, wages for the necessary laborers have risen, as well as the freight rates from the more distant timbered areas in the northern parts of the country. These circumstances have run up the price of charcoal to about double what it was prior to the turn of the century.

Of course, the iron makers have generally endeavored to reduce charcoal consumption. One of the steps taken before the War was to build electric blast furnaces at some steel works fortunately in possession of cheap hydro-electric power. Electric pig iron is produced with about half as much charcoal as in the conventional blast furnace.

The use of ore concentrate also economizes furnace fuel; this practice has consequently increased during the last decade. Furthermore, open-hearth furnaces are now-a-days charged with less pig iron and more scrap; while this saves solid carbonaceous fuel, it has, at the same time, raised the demand for melting scrap and thus has turned attention toward a prompt solution of the sponge iron question discussed in the previous letter.

Through combined efforts such as the ones outlined above, the consumption of charcoal has dropped to about half what it was before the War, now amounting to about 2,000,000 cu. m. a year, of which something like 20% is produced in charring furnaces.

At the same time that these modifications have been made in the iron and steel plants, attempts have been made (and today are continuing more intensely than ever) to produce sounder and cheaper charcoal. A group of three interested parties, (a) the Jernkontoret, (b) the Swedish Academy of Technical Sciences and (c) a charcoal manufacturing firm, belonging jointly to some of the biggest iron works, have started a research institute to work on the productivity of the process and the recovery of by-products. Part of the work of this institute is also supported by the Government. Its leader is Hilding Bergström, well known in Scandinavia as expert in the domain of charcoal research. He has made a number of valuable contributions to our knowledge of this product and the methods of production.

The institute just mentioned has a special consulting department for advising on all technical phases of charcoal production. Its activity has already resulted in a number of economies, so that it seems possible that, when the present depression in trade will have passed over and the demand for charcoal will again rise, the prices, nevertheless, will not soar as high as during the years before the War.

A. WESTGREN

Stockholm, Sweden.

Liege Congress Discusses Alloys

SEVERAL meetings marked the centenary of Belgium's independence, among which the sixth International Congress of Mines, Metallurgy and Applied Geology at Liege must attract the attention of metallurgists. It was attended by more than a thousand members, and so numerous were the communications that those treating of metallurgy had to be divided into six sections; namely, blast furnace, steel works and ferrous alloys, foundry, non-ferrous metals, non-ferrous alloys.

The addresses will be published either complete or in abstract in the *Journal* of the Congress. Some of them will also be reprinted in the trade press. France had a preponderating share of authors and audience, because of her geographical vicinity and her affinity of culture with Belgium. The quality of the essays relating to the following subjects should be noted:

Cleaning and thermal regeneration of blast furnace gases,
Tempering of steel,
High chromium steels,
Development and heat treatment of light aluminum alloys.
High-strength and special cast iron,
Physical tests of cast iron,
Chromium and nickel plating.

The chief advantage of an international congress — and a very important one indeed — is to emphasize the current questions which are occupying the attention of the whole scientific world. Aside from the great general problems of more scientific and speculative interest (such as, for instance, the mechanism of the heat treating reactions and the relationship between the properties, constitution and structure of metals and alloys), the above list indicates the two characteristic problems of modern times and the present requirements of industry:

1. The search for those corrosion-resistant steels and alloys, already so necessary to the chemical industry and being more and more employed in every-day use. In the same category may be mentioned improvements in metal coatings, such as electrolytic plating, painting, varnishing and surface treatment by chemicals.

2. Searches for stronger alloys of light weight. Such materials are vital to aeronautics; a demand for them arose first in the automobile industry and now is extending into the railway industry and shipbuilding.

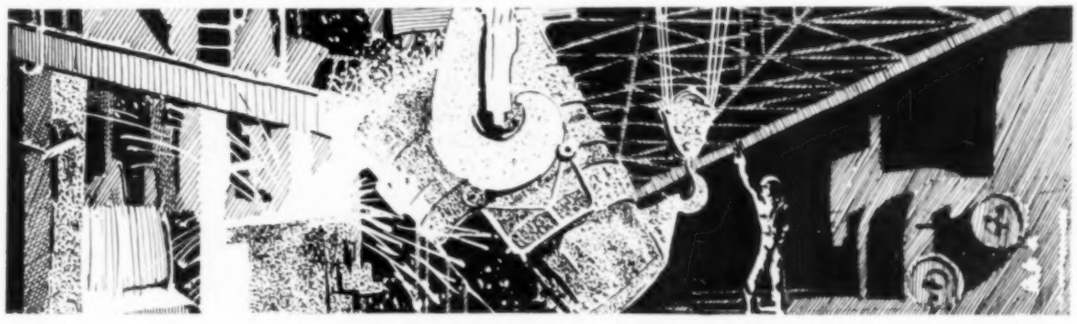
The creation of new types of alloys, whose growth was extraordinary, happily solved these two problems. We refer to the stainless high chromium steels and the light hardened alloys of aluminum containing one or more of the three elements, copper, magnesium, silicon.

We shall have occasion to speak again of this matter, because there are other methods of approximating the results already obtained in the stainless steels. As the writer pointed out at the Congress, valuable alloys for resisting chemical attack are formed if iron is alloyed with molybdenum, tungsten, aluminum, tantalum or zirconium instead of chromium.

Metallurgy has consequently done its part in the solution of the two characteristic problems of the present times: First, the increasing price of manual labor requires metallic articles intrinsically more durable and also requiring less expense for preservation and repairs; and secondly, the increasing speed of all conveyances involves the necessity of decreasing the weight of the moving parts of the vehicle.

ALBERT PORTEVIN

Paris, France.



Speedier . .

MALLEABLE

melting and annealing

MALLEABLE cast iron has in recent years experienced quite a flurry, in fact almost a fury of investigation. Strenuous competition has led producers to strain for improved methods and product. Some of the results so far obtained will be outlined in what follows.

It will simplify the discussion to consider that the manufacture of malleable cast iron consists of two steps: First, casting the metal into shape as hard iron, and second, annealing these castings to form the strong, ductile, easily machinable metal the customer desires. The latter part of the process has received the major share of attention by far.

By
L. H. Marshall

Melting and casting ("the embryology" so to speak) have not been probed as deeply as the more adult phases, but they still have come under the eyes of the doctors of metallurgy. Improvements in natal treatment have resulted.

For instance, the use of sodium carbonate in air furnace melting is now considered improved practice in many plants. Its effects are worth considering.

While soda ash additions have proved to be an efficient desulphurizer in cupola melting, and this object can be accomplished in hard iron from an air furnace, other effects are probably of more importance. Although high sulphur

pig iron can be purchased at a lower price, the malleable producer usually prefers to play safe, use low sulphur raw material and be sure that the iron will be right. Sulphur reduction by caustic is reserved for heats inadvertently high in sulphur, or it is used to correct high sulphur built up in the return scrap.

One of the best arguments for the use of soda ash seems to lie in its influence on the slag. When the caustic is added to the charge before firing, it is the first to melt down and covers the initial pool of molten iron with a protective slag that cuts down oxidation. Then as the normal slag forms, the soda ash lowers the fusion point and gives a much thinner and more fluid slag than usual, which in turn promotes the passage of heat to the metal and the elimination of non-metallic inclusions. All of this results in an earlier skimming of the melt. With the slag removed, the metal superheats more readily. Melting time is saved together with some fuel.

While there are some chemical actions involved in the interaction of slag and soda ash, particularly the reduction of much of the iron oxide present and return of this metal to the bath, the chief gain results from the lowered fusion point of the slag, as described.

If it is desired to lower the sulphur content of the melt, an addition of caustic is made shortly before pouring. The metal should be thoroughly skimmed before this treatment, as the soda ash will react with the silicates before it will react with the sulphides. Consequently the former should be eliminated as far as possible if the treatment is to be effective. It is not wise to let this caustic slag remain on the bath too long if the maximum results are desired as the reactions involved are reversible. That is to say, sulphur tends to leave the slag and re-enter the melt after a time.

High sulphur heats may, of course, be treated with ferromanganese instead, but manganese sulphide thus formed does not always pass off completely in the slag.

The caustic treatment has the further advantage that by reducing the oxides in the molten iron, a quieter, more fluid metal results. It should be noted that soda ash reduces the amount of silicon in the metal. Allowance for this loss should be made. The drop in silicon content is particularly noticeable in all-scrap heats, or others where the amount of oxidation is unusual.

Two points should be observed:

1. Add caustic early in the heat to reduce oxidation and produce a fluid slag that permits an early first skim.

2. Add caustic shortly before pouring to desulphurize the melt and give a quiet and fluid heat of metal.

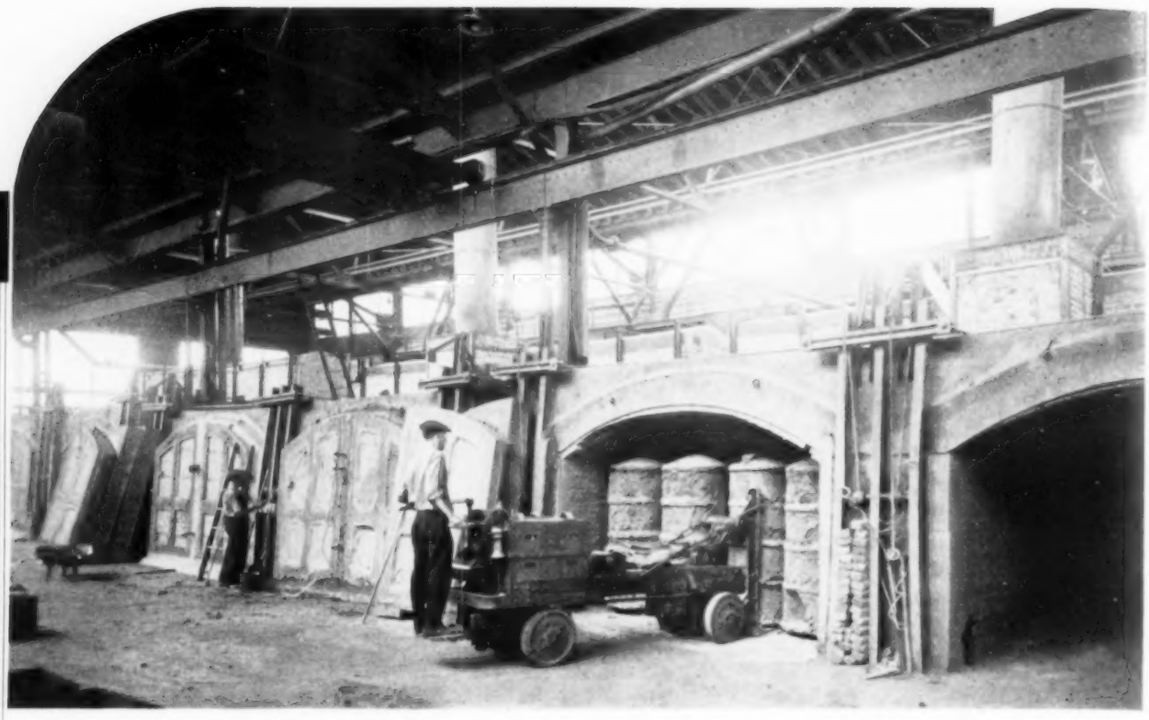
Air-furnace melting is an intermittent process and as such does not fall exactly in line with the modern production methods. As a result, there has been a trend among large producers toward "duplexing." While this is not a new process, it has been finding wider use of late. This method is commonly done by melting in a cupola and then conditioning in an electric, open-hearth, or air furnace. While some economies are possible through the use of cheaper raw materials, the great advantage is that a supply of molten metal is constantly ready for the molds.

Advantage can then be taken of sand handling and mold handling equipment, and continuous production in a minimum space at a lower labor cost is realized. But since the full economy of such a layout is only secured when used on a large production of a relatively few types of castings, the number of such installations is probably limited.

Annealing Can Be Shortened

Passing now to the second step in the manufacture of malleable iron castings, namely the annealing process, we find that it apparently appeals to most investigators as the most likely field of improvement, requiring, as it does, from 5 to 14 days. A number of plant managers have built special furnaces to try out their own ideas on quick and more efficient annealing. Many others are cutting the time allowed in their present furnaces, in an effort to supply rush orders in a much shorter time than formerly possible.

It has been recognized for some time that the usual commercial annealing cycle does not take advantage of the full possibilities in the rate of annealing. In fact, a generous margin of safety is intentionally present so that castings that are anywhere near normal in behavior will be sure to come well malleablized.



There is a number of factors that cause variations in the annealing time in the direct-fired, box-type furnace. First, there is the variation in composition of castings not only from melt to melt, but even from start to finish of the same melt. Then, the thickness of section influences the rate; thin castings generally anneal faster than castings with heavy sections poured from the same metal.

Slowest Rate Must Govern

It thus becomes evident that the castings coming to the annealing room do not have a uniform annealing rate. Naturally the cycle used in practice must be selected to malleablize not the average but the slowest iron. As a result, the experimenter may start off with a fairly rapid cycle but soon finds that a heat comes through somewhat under annealed. He hastens to prevent a recurrence of that trouble and lengthens the time of anneal. Success crowns his efforts for a time but eventually another poor heat makes its appearance. Again the anneal is lengthened. Finally he is likely to end with an anneal that is discouragingly longer than the first cycle tried.

There is a brighter side to the picture, however. Certain factors about the annealing process as usually carried out encourage the hope that substantial improvements may be possible in other directions.

Atmosphere in the direct-fired box-type furnace so much in vogue is strongly oxidizing, and requires that the castings be protected from the furnace gases. The result is that the pots and packing used for protecting the castings usually outweigh the castings treated. And a further effect is that a sizable heating chamber is required for a relatively small bulk of castings, and it is by no means easy to maintain a uniform temperature through such large spaces.

The regular method of annealing malleable cast iron, therefore, expends much time and fuel on heating the furnace itself and the packing material and containers, all of which are extraneous to the main object of heating the castings. Finally, when the furnace has reached the desired temperature, the heat is not uniform nor under exact control.

These limitations are seen to be rather weighty handicaps when we consider the fundamentals that make for rapid and efficient annealing of hard iron. The process of annealing consists of two essential steps: First, hold the

iron at a temperature well above the critical point (roughly 760° C., or 1400° F.) until equilibrium is reached. Second, maintain the temperature below the critical point until graphitization is complete. (Since the critical point varies slightly in various irons, it is usual to cool very slowly through a small range in its neighborhood so as to make absolutely sure of good results.)

Rapid annealing requires that the first step should be carried out at as high a temperature as possible. It is known, for instance, that the usual malleable iron will graphitize and reach equilibrium ten times as fast at 980° C. as at 815° C. Practical considerations, such as distortion, limit the upper temperature that may be used, and this practical limit is likely to vary with the type of castings produced.

For most rapid work, the second step, which completes the anneal, should be carried out slightly under but very close to the critical point. It would appear that exact temperature control is the important factor here.

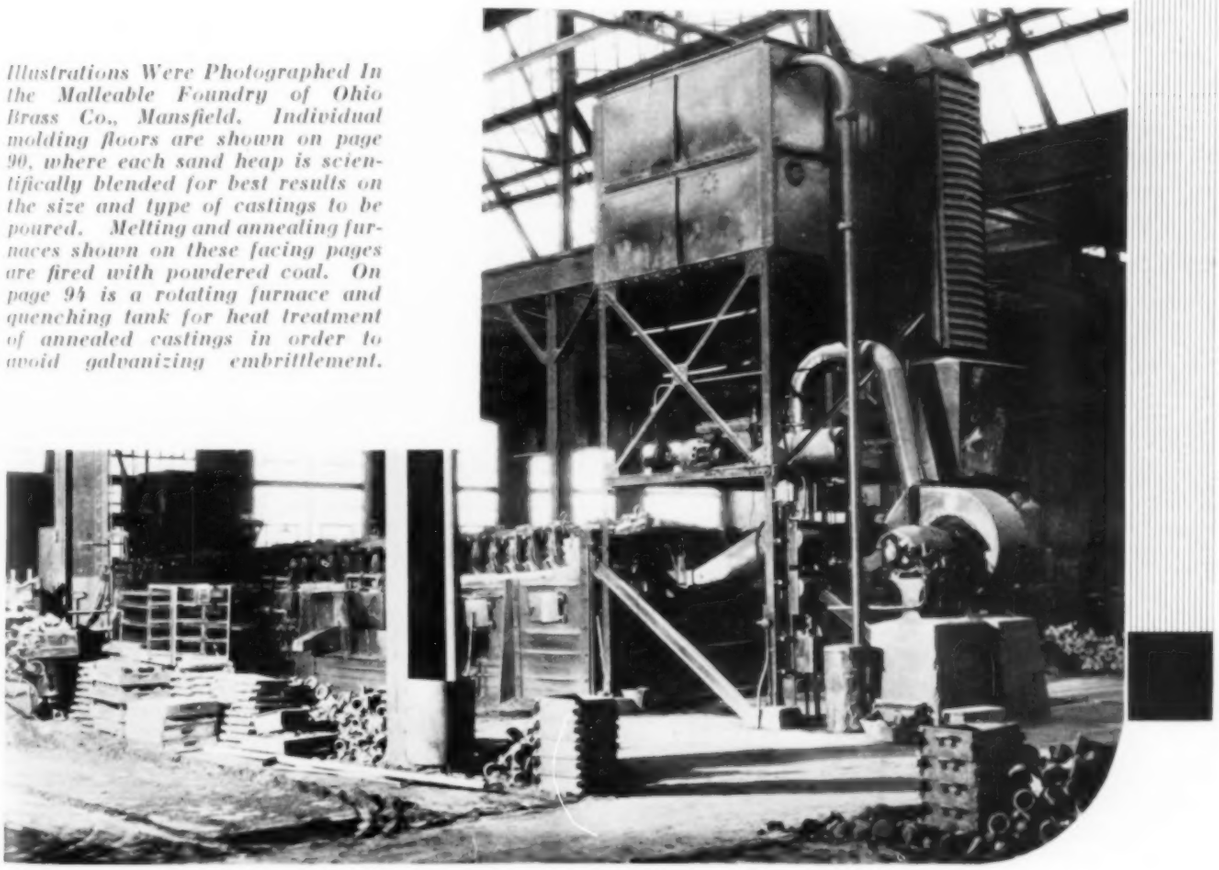
With the object of performing the annealing operation more efficiently and rapidly, and at the same time making it a continuous process, the tunnel kiln has been tried out. While these objectives were reached in part, the high initial investment and lack of flexibility as to amount of castings treated have operated against its extensive use. A number of producers have tried small furnaces designed for more exact temperature control.

Electric Annealing Furnaces

An interesting example was described by I. R. Valentine in *Metals and Alloys*, November 1929. His special electric furnaces have the outstanding advantage of accurate control, but are handicapped by high cost of electric heat. No containers or packing material are used by him.

The process is carried out in two box-type furnaces, one constantly held at the upper temperature, 925° C. (1700° F.), and the other near the critical point, about 730° C. (1350° F.). The

Illustrations Were Photographed In the Malleable Foundry of Ohio Brass Co., Mansfield. Individual molding floors are shown on page 90, where each sand heap is scientifically blended for best results on the size and type of castings to be poured. Melting and annealing furnaces shown on these facing pages are fired with powdered coal. On page 94 is a rotating furnace and quenching tank for heat treatment of annealed castings in order to avoid galvanizing embrittlement.



castings are stacked on a car and run into the hot chamber and allowed to remain there until they reach temperature, plus a sufficiently longer time to permit equilibrium to be established. The car with hot castings is then removed to the second or low-temperature furnace. Here the castings cool rapidly to 740° C. and very slowly, about 2° C. per hr., to 720° C. Further cooling may be as rapid as desired. The total time may be as low as 30 hr. The resulting castings are thoroughly annealed and consequently very readily machinable. The surface, however, tends to be more oxidized and scaly than that of castings protected by packing material.

(Speaking of oxidation, it may be parenthetically mentioned that a process has recently been developed for producing castings bright and untarnished as they are dumped from the annealing pot. They may be galvanized immediately without any intermediate cleaning.)

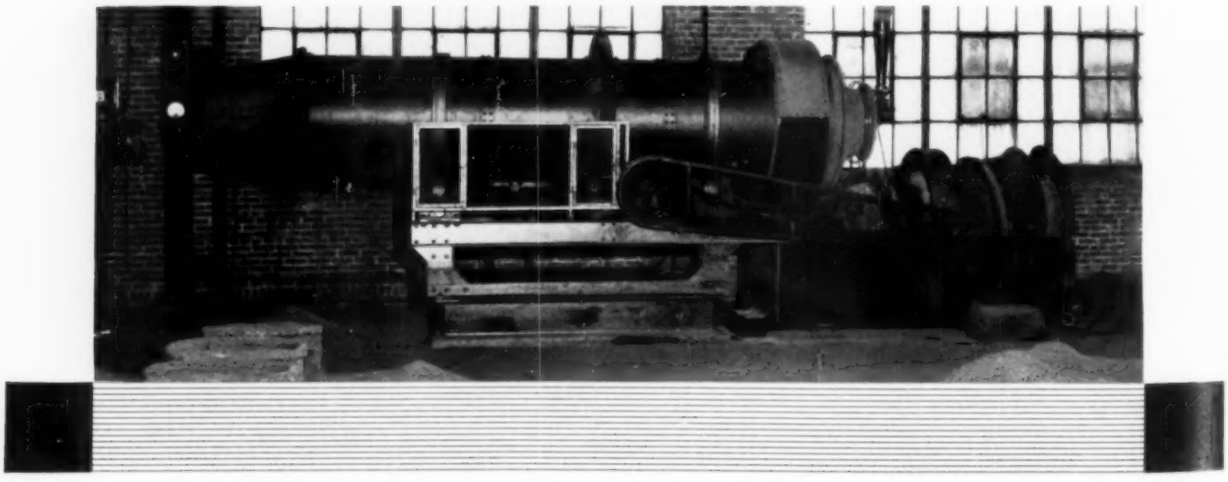
Mr. Valentine's process takes ordinary malleable iron and speeds up the anneal about to the limit. A new departure in annealing has been developed by H. A. Schwartz that materially increases the rate. Its essential feature is that the castings must be rapidly cooled from above the critical point before annealing. This quick cooling may take place as the metal is cast, or the iron may be reheated to above 760° C. (1400° F.) and then quickly cooled. It would appear from this that castings made in permanent molds ought to anneal more quickly than castings made in sand molds. The annealing rate is influenced by the rapidity of the quench, but the inventor states that the high temperature annealing period may be reduced to one-fourth or even one-tenth its normal time.

Some annealed malleable is now being heat treated. The Flecto process may be cited as an example. This process has been patented by the author and consists in quenching the iron from a temperature slightly under the critical point (about 1200° F.). This eliminates the galvanizing embrittlement and the low temperature embrittlement frequently encountered in malleable iron otherwise of high quality.

Special Malleable for Chain

Another post-anneal treatment is carried out by some makers of malleable iron chain. The annealed iron is heated slightly above the critical point for a short period to recombine a small amount of the carbon. The result is a stronger, stiffer iron of lower ductility than the usual product. Naturally, such metal would be more difficult to machine and its application is limited. Chain producers are even case hardening the links to increase wear resistance. Malleable iron after such treatment would, of course, depart widely from the accepted type.

While many of the ideas and methods advanced at present may be only sparks from the torch of progress, and as such glimmer faintly and die out, there can be no doubt that industry is eager to fan them into flame. With such evident desire for advancing the art, there is reasonable hope that some notable advances are being or will shortly be made.



· R-101 ·

Facts about the Ship

WHEN, early in October, the world's largest airship, R-101, was destroyed shortly after starting its maiden voyage with appalling loss of life, many involuntary questions arose about the folly or the wisdom of building such huge yet such fragile structures. Some facts will doubtless aid in forming a correct conclusion.

Englishmen have been particularly unfortunate in their airships. R-33, R-34 (a ship 79 ft. in diameter which flew the Atlantic in 1919) R-35, R-36, R-38, R-40 all came to untimely ends through accident. R-38 was most tragic, breaking in two when making a quick turn, falling into the Humber with loss of many lives.

For some time after that disaster, interest in airships practically ceased. But the Government ultimately became convinced that imperial communications required airship service from London to Egypt and India. Consequently two airships, R-100 and R-101, were authorized, together with necessary hangars, mooring masts, gas plants, and meteorological stations at Cardington, Ismailia and Karachi, in the three countries named. As announced recently in Parliament, the necessary research and development work cost £305,000, the two ships £894,000 and the sheds, mooring masts and meteorological stations £1,100,000, a total of approximately $11,000,000. In view of the successful trans-Atlantic flight of the R-100 during the summer, the Government had already contracted for the design of a ship of that type but half as large again, which it was confidently expected could be operated as "a commercial proposition" between England and Canada.

To revert to the beginning: Airship Guarantee Co. of Howden contracted for the R-100. The company is owned jointly by Commander C. D. Burney, and Vickers, Ltd. The designer was B. N. Wallis.

R-101 was erected under Government supervision at Cardington; the metal work was fabricated by Boulton & Paul of Norwich. Lord Thomson, air minister, personally interested himself in the work; the designer was Lieut.-Col. V. C. Richmond, R. B. B. Colmore superintended the erection. All were killed in the wreck.

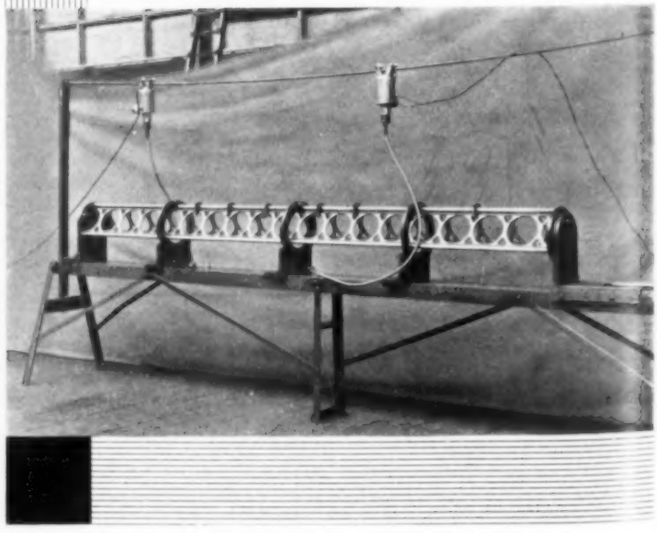
Specifications for the two ships were alike. Each was to have 5,000,000 cu. ft. capacity, a minimum speed of 70 miles per hr. at 5,000 ft. elevation, to be able to cruise 4,000 miles at 63-mile speed with one load of fuel, to have

"The Big Bus", as the R-101 Was Known to Englishmen, On Its First Trial Trip Last Autumn. On page 97 is shown the interior of the lounge, and the glass-enclosed promenade beyond where passengers could view the landscape.

accommodations for 100 passengers, and to conform to the safety requirements set up by a consultative board. As to details of construction, the designers were given free rein.

Following the indications of experiments on models at the National Physical Laboratory, both accepted a short, thick shape for the hull. Overall dimensions were as follows: Length of R-100: 709 ft.; of R-101: 724 ft. Maximum diameter, 133 ft. and 132 ft. respectively. Estimated lift of R-100: 156 tons, of R-101: 150 tons. During the winter the R-100 was lengthened one panel (about 45 ft.) which increased her capacity to 5,500,000 cu. ft. and gross lift to 166 tons.

Aside from the original dimensions and the fact that both ships used hydrogen for buoyancy, there was profound difference in nearly all details of construction. Thus, main frames on the R-100 were 16 sixteen-sided polygons made on the Zeppelin principle — that is, of straight girders of moderate depth tied to a central ring by radial cables. R-101 had 16 fifteen-sided polygonal frames, but each ring was structurally complete without wiring to the center or across corners. R-100 has a longitudinal girder down the axis of the ship, passing through gas bags and rings at the center of main frames. R-101 had no keel reinforcement.



Main Frames Were Made and Braced With Sheets Having Triangular Cross-Section. The three "booms" of each girder were of stainless steel strip, curled into an open circle with edges flared out to rivet to punched duralumin sheets, acting as webbing. Each girder was accurately fabricated to very close overall tolerances and pin connected to all intersecting members. (Photos copyrighted by British Air Ministry.)

Skeleton of R-100 is duralumin; the R-101 used 24.9 tons of stainless steel, representing 55% of the metal in the hull; 35% more is accounted for by aluminum alloy webs and fittings and 10% by swaged steel wire and cable bracing.

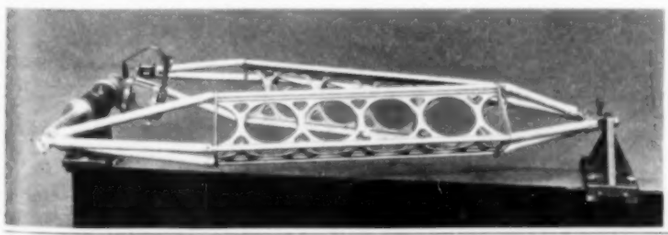
Outer envelope of R-100 is kept taught by tieing it down to an internal system of wire mesh so that the surface is in effect a series of 16 corrugations curved inward in concave arcs. In R-101 reliance was placed on 15 reefing booms running from stem to stern, midway between the main longitudinals, which could be jacked outward and thus convert the envelope fabric into a taut 30-sided circle.

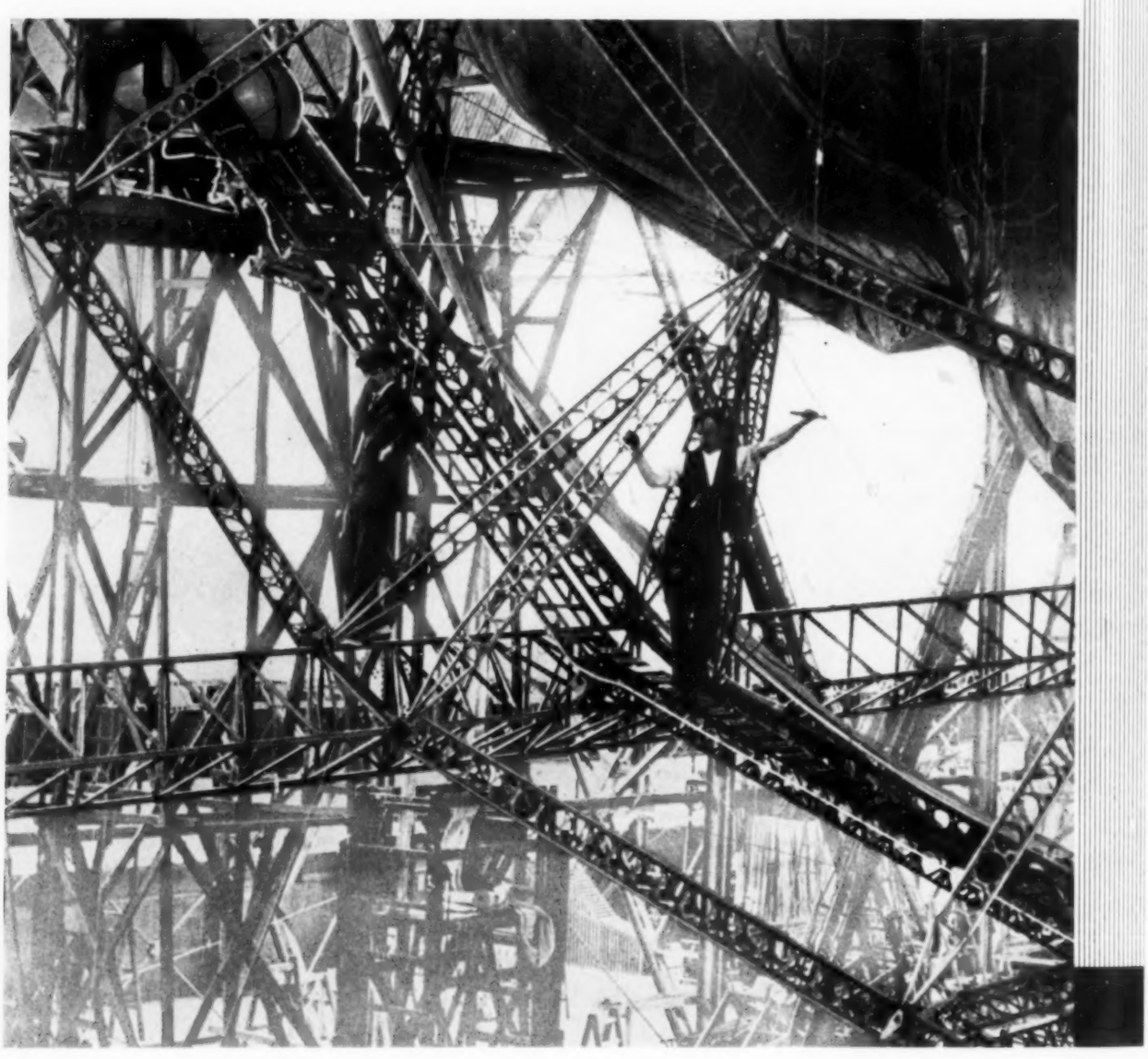
Six Rolls-Royce "Condor" gas engines (660 h.p.) are mounted in three cars under the R-100. Engine shafts are in-line; thus half of the propellers are tractors, half pushers. Rear engines are all reversible by a gear shift. On the other hand R-101 had five 8-cylinder Beardmore "Tornado" heavy oil engines, each in a separate car. These were designed to develop 650 h.p. at 1,000 r.p.m., but serious vibration necessitated reducing this speed, whereupon the power output became 585. Furthermore, it was originally intended to use hollow steel pusher propellers, attached to the shaft by a loose boss which would permit the pitch to be changed by hand. The steel blades cracked under the torsional stresses of operation; when wooden blades were substituted they could not be secured satisfactorily to the reversing bosses. Consequently, when the R-101 started on its last journey four engines totalling 2,340 h.p. were available for forward flight; the fifth was idle and had a propeller set to back the ship if required during mooring to a mast. In comparison with the 3,960 h.p. in the R-100, the wrecked vessel seemed seriously under-engined.

It was admitted that these oil engines are very heavy — 8 lb. per h.p. as installed is the official weight (in total adding 2½ tons to the original estimated load). However, consumption of heavy fuel is very much less than light gasoline — 0.35 lb. and 0.55 lb. per brake h.p.hr. are the figures. On this account the weight of engine plus heavy-oil fuel necessary for flights longer than 50 hr. becomes less than the corresponding weight of gas engine and gasoline. Furthermore, for every pound of fuel used an equivalent amount of valuable hydrogen must be wasted to maintain stability in flight. Much was made of the relative safety of oil with its low flash point; also that high volatile gasoline is unsuitable for flights in the tropics.

Coming now to the details of construction of the main skeleton, we find that both ships use girders with triangular cross section — each girder or strut has three chords or booms equally spaced apart by diagonal members or webs.

The booms for R-100 are duralumin tubing made in 40 to 50-ft. lengths by winding standard strip into spiral form and riveting the overlap.





Workmen Are Standing On Longitudinal Girder At Its Intersection With a Main Frame. Frames were made structurally complete, needing no wire ties to the center, by fitting together three rings, two near the outer envelope, and the third some 10 feet within. At each of the 15 angles in the polygon forming this frame are four struts, splayed out from the pin at their inner end and joining the outer polygons at their intersection with the longitudinal girder.

Small gussets for the diagonal web members lacing the three booms together were also riveted at proper intervals. Rivets were blown up inside the tube pneumatically, about 24 per foot of helical seam, and closed with machinery.

Sixteen of these standardized girders formed a simple ring; at each corner of the polygon was the intersection of a main longitudinal girder; the four members met in a spider-like fitting, with all wire connections leading to its geometric center. It is said that in the entire hull, tail structure and framing for passenger quarters, no more than 50 standard parts were used.

In order to make the main frames in the R-101 structurally complete without wiring between opposite polygon angles it was necessary to construct each one of three rings. The view of the ship under construction, printed above, shows clearly how this was done. Two series of girders, each forming a 15-sided polygon close to the outer circumference of the ship, were placed about 10 ft. apart *(Cont. on p. 162)*

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Physical properties are dependent as much on the soundness of the casting as they are on chemical analysis; obviously an unsound casting will give an abnormally low result in any composition. Given laboratories have no trouble in agreement.

DIE CAST TEST BARS OF ZINC BASE ALLOYS

Alloy No.	Desired Chemical Analysis				Purity of Zinc	Physical Properties of Test Bars, Not Aged			
	Copper	Aluminum	Magnesium	Others		Tensile Strength Lb. per Sq. in.	Elongation in 2 In.	Rockwell Hardness	Charpy Impact Ft.-Lb.
XIII	5.0	0.25	—	—	99.90	26,000	0.5	75	1.0
XIV	3.0	4.0	—	—	99.90	43,000	1.5	85	2.0
XV	3.0	4.0	0.1	—	99.90	45,000	1.5	90	3.0
XVI	3.0	4.0	0.1	—	99.94	45,000	1.5	90	3.5
XVII	3.0	3.0	0.3	—	99.90	39,000	1.0	100	1.0
XVIII	3.0	0.5	—	6.0 Sn	98.40	23,000	1.0	55	1.0
XIX	2.0	4.0	0.1	0.02 Ni	99.94	45,000	3.0	85	7.0
XX	3.0	4.0	—	—	99.75	38,000	1.0	85	2.5
XXI	3.0	4.0	0.1	—	99.98	45,000	3.0	85	7.0

tween the ultimate strength of the alloys, but impact strength varies considerably.

Specific gravity of aluminum die castings varies between 2.7 and 2.9; approximately 0.1 lb. per cu.in.; the silicon alloys are the lightest, and the alloys high in copper and nickel the heaviest.

Plating and Machining Die Castings

Aluminum die castings in general are fairly easy to machine. Silicon alloys sometimes give trouble, and any of them is subject to "hard spots", that common complaint of the machine shop. They are readily polished, those with the higher nickel contents taking a high polish more readily.

Plating of aluminum alloys is one of the newer developments. It was generally regarded with suspicion before the findings of H. K. Work were presented to the American Electrochemical Society in 1928, but since then, more and more of it is being done. Aluminum die castings lend themselves particularly well for the acid dips recommended by Dr. Work.

These alloys can be soldered on occasion, but soldering is not recommended because of the danger of electrolytic corrosion between the aluminum in the casting alongside the tin in the solder.

The distortion and deterioration of physical properties of the old-time zinc base die castings do not occur in the aluminum alloys. The impression remains in some quarters that *all* die castings containing aluminum are likely to exhibit this undesirable characteristic unless properly handled; while as a matter of fact it applies only to certain zinc base alloys containing aluminum. Aluminum base alloys, either sand cast or die cast, are as permanent in size and shape as brass, and their physical properties change only slightly, incident to age hardening.

It is generally agreed that the use of aluminum alloys will expand greatly in the future, as decreased weight becomes more and more important with the advent of faster transportation both on land and in air. The work of the A.S.T.M. committee on die castings will have a standardizing effect on the industry. Tentative specifications have been written simplifying the list of alloys shown below to No. IV to IX inclusive, the others having already been judged to be obsolete, or possessing no properties not better secured by one of the compositions retained.

Now that the physical results to be expected from present-day die castings are known, they will also find their place as an engineering material.

DIE CAST TEST BARS OF ALUMINUM BASE ALLOYS

Alloy No.	Desired Chemical Analysis			Iron Pick-Up (Maximum)	Physical Properties of Test Bars, Not Aged			
	Copper	Silicon	Nickel		Tensile Strength Lb. per Sq. in.	Elongation in 2 In.	Rockwell Hardness	Charpy Impact Ft.-Lb.
I	4	—	—	2.5	30,000	4.5	55	6.5
II	10	—	—	2.5	35,000	2.0	75	3.5
III	14	—	—	2.5	36,000	1.0	90	2.0
IV	—	5	—	2.0	29,000	3.5	60	4.5
V	—	13	—	2.0	33,000	1.5	60	2.0
VI	2	3	—	2.5	30,000	3.5	60	5.0
VII	4	5	—	2.25	32,000	2.0	75	2.5
VIII	1.5	0.75	2.25	2.5	29,000	4.0	55	4.5
IX	4	1.5	4	2.5	31,000	1.5	75	2.0
X	—	2	5	2.25	28,000	2.0	55	3.0
XI	2	8	—	2.25	32,000	1.5	75	2.5
XII	8	1	—	2.5	33,000	2.0	80	3.0

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Memorial Lecture (Continued)

Of course, by this time, you are already expecting me to say that the difference is due to dissolved oxygen. And I shall not disappoint you — indeed I think so.

But the problem is more complex. Why should there be a large amount of dissolved oxygen in some cases, and but a small amount of dissolved oxygen in others? Possibly something in the one steel promotes the solution of oxygen, or in another steel obstructs the solution of oxygen.

Now it is well known that steels very high in manganese are usually normal, whereas steels very low in manganese are frequently abnormal. It would seem possible that manganese obstructs the dissolving of oxygen, with the result that when manganese is present and the dissolved oxygen consequently low, the diffusion of carbide is slow, this being a reason for high manganese steels being normal.

At this point we recall that steels absorb oxygen during carburizing. Now if manganese, as we postulated, obstructs the solution of oxygen, then possibly high-manganese steels would absorb but little oxygen in carburizing, whereas low-manganese steels might absorb large amounts.

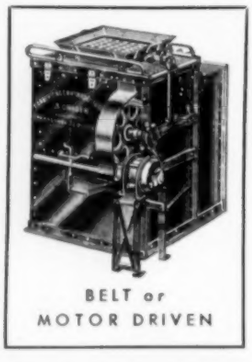
This reasoning led to some successful experiments — if the experiments had not turned out as predicted we should, of course, not have mentioned them here. But we do as a matter of fact find, as we can see in the diagram on page 36, that steels low in manganese absorb large amounts of oxygen in carburizing, whereas steels high in manganese absorb relatively small amounts of oxygen.

The diagram shows also, however, that this relationship between manganese and absorbed oxygen is not by any means perfectly regular. It is not only that slight increases in manganese sometimes fail to cause a decrease in absorbed oxygen, but in one case even, designated by the letter *A* in the diagram, a steel of intermediate manganese absorbed very much more oxygen than any other steel either lower or higher in manganese. We can only conclude from this that, whereas we believe we have discovered one factor which influences the absorption of oxygen in carburizing, there must be other factors yet to be discovered.

Regardless of the reasons why oxygen is absorbed, once it *is* absorbed it has some interesting effects on the structure, and it is these effects that we propose to discuss now.

The ten steels just described prove upon microscopic examination to form an instructive group. We find a pronounced trend in the degree of abnormality, that is to say, in the amount of free ferrite. This trend is expressed by saying that the amount of free ferrite is dependent, not on the total oxygen content of the steel, but apparently almost solely on the amount of oxygen absorbed in carburizing. This is illustrated on page 37. The arrows point to the significant areas. These three photographs are typical of the conditions found in the ten steels of the series.

It would seem to be true, at least for the carburizing steels in general use, that the oxygen which remains as a residue from the melting is in a form not readily *(Cont. on page 104)*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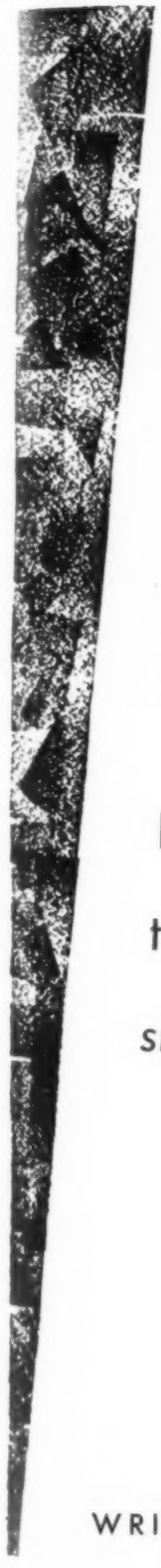

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dissolved at steel treating temperatures. *That* oxygen is present largely as inclusions of the silicate type, because the steel is usually a so-called killed steel, containing appreciable amounts of silicon. The ten steels with which we have just experimented were of that type.

But let us return to our statement that it is usually only the oxygen absorbed in carburizing that leads to free ferrite and causes abnormality. At this point, we are in hopes that you desire a little further evidence, for the very good reason that we are about to offer you some. And our procedure is this: If it is absorbed oxygen that causes abnormality, then obviously if a steel could be carburized without absorbing oxygen, it should remain normal and show no free ferrite.

We therefore carburized other samples of the ten steels discussed before, and, bearing in mind the researches of Sykes, Guthrie and others, did it with methane derived from natural gas. Whereas in pack- or CO-carburizing the greatest gain in oxygen reached as much as 0.071%, in methane (CH_4) carburizing, the greatest gain was only 0.013%. That there was any gain at all is probably an index that the gas was not quite pure.

And now we come to the structures under the microscope (page 37). We find that none of them show free ferrite or abnormality to any appreciable extent; in other words, the steels have remained quite normal!

We find then, distinct evidence in these ten steels that the degree of abnormality or amount of free ferrite was proportional to the amount of oxygen absorbed in pack carburizing, and that when the absorption of oxygen was prevented, the steels showed a normal structure.

And now a final word as to this normal structure. We have talked very glibly about speed of diffusion of the carbide, saying that when dissolved oxygen was present, the carbide diffused faster. That is, in the presence of dissolved oxygen, the carbide of the pearlite diffused out and deposited on the hyper-eutectoid cementite at the boundaries of the grains, leaving free ferrite, but when dissolved oxygen was *not* present, the diffusion was so slow that the carbide was unable to migrate sufficiently and the structure remained normal. But if these differences in diffusion *(Continued on page 106)*

Who's Who in the alloys —and WHY

NIROSTA METAL PROVIDES MAXIMUM DUCTILITY AND RESISTANCE—ONLY OBTAINABLE WHEN PROCESSED UNDER KRUPP NIROSTA PATENTS BY THESE LICENSEES:

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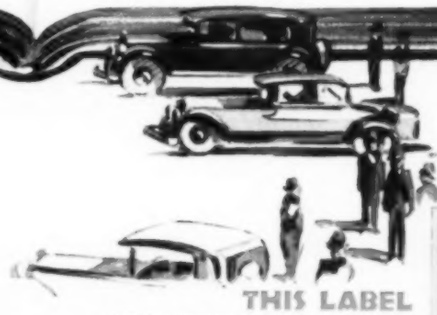
THESE 49 COMPANIES, representing the majority of America's best mills, factories and experience in the alloy field, became licensees only after scientific and practical investigation of Nirosta.

Combined under the Nirosta banner, and interchanging research and application experiences, they constitute a recognition and a service never before equaled in the introduction of a new metal.

Nirosta, the aristocrat of alloys, has many advantages which are not duplicated by any other metal; the Krupp heat treatment (high temperature), analyses, and a wealth of continuous research and application experience —the approval of its non-corrosive and practical working properties by many of America's finest industrial laboratories and engineers —and the background, service and manufacturing facilities represented in the list of Nirosta Licensees.

THE knowledge gained in the application of non-corrosive metals in this country and abroad is available to you in the form of specific recommendations after a complete study of your problem.

Write your producer or to Krupp Nirosta Company, 2638 New York Central Building, New York, N. Y.



THIS LABEL IDENTIFIES NIROSTA

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made either to specification or our own formulae, are accepted as STANDARD because; we use the highest grade materials, our laboratory checks our manufacture, and our products are sold with a guarantee of maximum quality at minimum cost per pound of steel carburized.

IT'S THE BRAND
THAT INSURES THE BEST RESULTS!

Lead Pot Covering
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Drawing Salts
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are found *within* the steels, we might reasonably look for differences also at the surfaces of the test pieces — that is, we might expect to find differences in the rate at which carbon diffuses into steel or diffuses out of it — in other words, differences in the rate of carburization or decarburization.

Now while the structure by which we judge abnormality under the microscope is formed during the cooling of the test piece after carburizing, it has been our belief that this structure is formed in the temperature range just *below* the critical point, that is, *after* the transformation from austenite to ferrite. That is to say, although the oxygen and the carbon are absorbed while the steel is austenite, the peculiar diffusion of the *carbide* which causes abnormality takes place only after the transformation to ferrite. The evidence is this: If a piece of normal and a piece of abnormal steel are carburized under the same conditions, the depth of carburization is likely to be about the same in the two pieces, differing usually by not more than one-tenth of the total, or at most one-fifth. This indicates that the speeds of diffusion *above* the critical point, i.e. during carburizing, are quite similar.

If the differences in diffusion in which we are interested occur *below* the critical point, then we ought to carry out the tests at that lower temperature and look for differences in the structure and properties.

The same ten steels were therefore packed in carburizing compound, and heated at 1250° F. for about 21 hr. At this low temperature the atmosphere in the mixture is decarburizing as to these steels, so that we find the surface layers not carburized but decarburized. And we are struck at once by the very great differences in extent of decarburization. Whereas *above* the critical point the diffusion of carbon into the steels differed by not more than one-fifth of the total, here *below* the critical point we find the carbon diffuses out of the steel to a depth which in some cases is 4 to 6 times as much as in others. And we find, as illustrated in the diagram on page 36, that the steels low in manganese decarburized the most, these being the same steels at the left of the diagram which, in general, absorbed the most oxygen, and were the most abnormal.

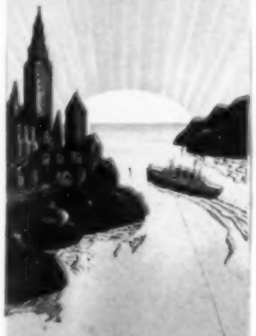
The twelve societies co-operating in National Western Metal Congress are:

American Chemical Society

American Institute of Electrical Engineers

American Institute of Mining and Metallurgical Engineers

American Petroleum Institute, Cal. Div.



American Society of Mechanical Engineers

American Society for Steel Treating

American Welding Society

Institute of Metals

National Purchasing Agents Association

Pacific Coast Electrical Association

Pacific Coast Gas Association

Society of Automotive Engineers

The Great Exposition Auditorium at San Francisco where the 1931 National Western Metal Congress and Exposition will be held

Remember your date
At the Golden Gate
In the winter of Thirty One
So make your plans, and don't be late
To arrive in the land of the Sun

A TRIP THROUGH THE WEST—California at its Height—a trip to Hawaii, if you wish—a weeks' sojourn in San Francisco attending . . .

NATIONAL WESTERN METAL CONGRESS

Where many subjects of vital interest to the metal world will be discussed during the sessions of the twelve cooperating societies (see left column) . . . Concurrently, over 100 manufacturers will exhibit the latest machinery, processes and production methods at

NATIONAL WESTERN METAL AND MACHINERY EXPOSITION

More than 70,000 square feet of exhibit space—at Los Angeles in 1929, over 50,000 visited the exhibits and sessions—a counterpart of the annual National Metal Congress and Exposition . . .

Over 200 Eastern people visited Los Angeles in '29—we expect 500 at San Francisco in '30

CIVIC AUDITORIUM
SAN FRANCISCO, CALIFORNIA
FEBRUARY 16—20, 1931

STATEMENT OF OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.,

Required by the act of congress of August 24, 1912, of METAL PROGRESS, published monthly at Cleveland, Ohio, for October 1, 1930, State of Ohio, county of Cuyahoga, ss.

Before me, a notary public, in and for the State and county aforesaid, personally appeared H. Kenneth Briggs, who, having been duly sworn according to law, deposes and says that he is the assistant business manager of METAL PROGRESS, and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, postal laws and regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business managers are: Publisher, American Society for Steel Treating, 7016 Euclid Avenue, Cleveland, Ohio; Editor and Managing Editor, Ernest E. Thum, 7016 Euclid Avenue, Cleveland, Ohio; Business Managers, W. H. Eisenman, 7016 Euclid Avenue, Cleveland, Ohio, and H. Kenneth Briggs (assistant), 7016 Euclid Avenue, Cleveland, Ohio.

2. That the owner is: The American Society for Steel Treating, 7016 Euclid Avenue, Cleveland, Ohio, which is an educational institution, the officers being: President, Robert G. Guthrie; Vice-President, J. M. Watson; Secretary, W. H. Eisenman; Treasurer, A. Oram Fulton; Directors, Zay Jeffries, F. T. Sisco, A. H. d'Arcambal, O. E. Harder and W. B. Coleman. The address of the above officers and directors is 7016 Euclid Avenue, Cleveland, Ohio.

3. That the known bondholders, mortgagees and other security holders are: none.

4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

H. KENNETH BRIGGS,
Assistant Business Manager.

Sworn to and subscribed before me this 30th day of September, 1930.

ARTHUR T. WEHRLE (Seal)
Notary Public.
(My commission expires October, 1931)

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FOR LEAD BATHS

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READERS' COMMENT continued

"Questions and answers on heat treating and pickling forgings," writes F. W. Anderson, general foreman, Newcastle, Ind.

Lawrence H. Seyfer, Asst. H. T. foreman, Ft. Wayne, wants "more, bigger and better stories."

"Just enough humor mixed with technical information to be interesting," writes Geo. E. Johnston, Asst. P.A., Detroit.

"Would like to see more alloy steel products used for all purposes," says E. E. Bartsch, engineer, Flint, Mich.

"Viewpoint on new processes in steel treating," says B. C. Cleveland, sales manager, Chicago.

"Application and economies of using Q-Alloys"—Geo. C. Thomas, M.E., Bridgeport, Conn.

Jerry Berkey, Cincinnati, writes, "Your house organ 'pumps' some good tunes. It is a layman's information sheet and should be kept in that category devoid of highly technical matter."

John E. Wiggins, Asst. Supt., Providence, would like latest news about heat treatment of alloy and carbon steel.

John R. Daesen, Chief of Research, Peru, Ill., says, "a little more technical data, corrosion resistance, failure of boxes, micros, etc."

R. E. Ludwig, Engineer, Irvine, Pa., wants "practical articles on live subjects by the man who knows."

Henry L. Decker, Technical Librarian, La Salle, Ill., would like a short summary of latest developments in the metallurgical field.

Robt. W. Ellingham, Mgr., Worcester, Mass., would like questions and answers on heat treating.

A. L. Stowell, Engineer, New Britain, Conn., would like more examples from practice.

C. B. Gwyn, Jr., engineer of Indianapolis, would like short notes on new materials or processes, special alloys, etc.

Duncan A. MacLeod of Buffalo wants further information on alloys in aviation.

Henry A. Brickner, Met., York, Pa., would like everything we have got on the bill of fare except dignity and also wants hot tips on the stock market.

"This new publication will make a good impression on the trade," says Edward T. Adams, M. E., of Binghamton, N. Y.

F. H. Kelly, Supt., Franklin, N. H., wants everything relating to furnaces and their use.

Morris Wing, Foreman Heat Treat, No. Quincy, Mass., says our stuff is always good enough to read—which after all is what counts—and would like "examples of unusual, clever time saving installations."

Theodore Packard, Physicist, Worcester, Mass., wants in each issue one full page rotogravure of some important industrial operation. We hope he doesn't mean the rise and fall of Willys-Overland or Murray Body.

J. H. H. Klein, Jr., foreman, Allenport, Pa., wants "more furnace information and man to man conversational writing."

Tom W. Whiting, Chemist, Muskegon, Mich., wants to know the effect of high sulphur fuels or gas on Q-Alloy boxes. The answer is: It increases oxidation, destroys surface appearance if sulphur is excessively high, but doesn't cause failure. We have boxes running in coal and producer gas fired furnaces giving excellent satisfaction.

Fred J. Hagerdorn, Met., Cincinnati, wants examples taken from actual experiences of users.

"What have you," says E. S. Brown, Met., of Chicago. Just you wait and see.

M. M. Hurst of San Francisco: "Just keep up what you have already started, we like it."

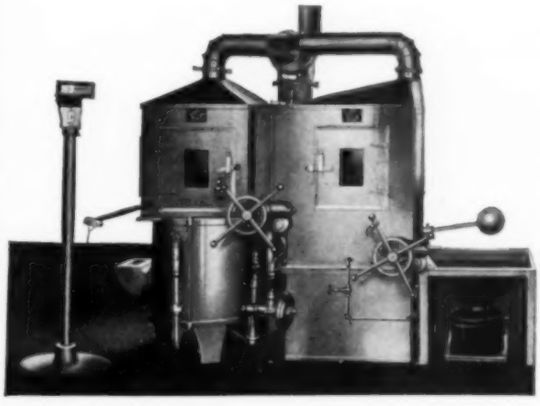
"Questions department," says C. R. MacCann, sales manager of Pittsburgh.

L. W. Kempf, Met., Cleveland, would like review of technical books and papers.

UNIQUE NEW TYPE OF POT FURNACE "HYRO-AUTOMATIC" INTRODUCED AT SHOW

HYRO Manufacturing Co., Inc., 200 Varick St., New York, offer this new furnace which is really a cyanide or salt hardening unit rather than just a furnace. It is a combination of furnace and quenching tank self-contained, each covered by a hood, the hoods connected and provided with Pyrex glass windows.

The work is fed with a scoop into a basket which is submerged in a hardening solution. When the pot treatment is complete the basket, which is integral with an arm swinging on a radius to register with the quenching tank, is swung out of the bath by a geared hand wheel to dumping position over the quenching tank, in which a similarly rigged perforated hopper is immersed. After discharge a reverse motion returns the basket for reloading and reimmersion while a second hand wheel swings the quench hopper to dump through a chute into a tote basket.

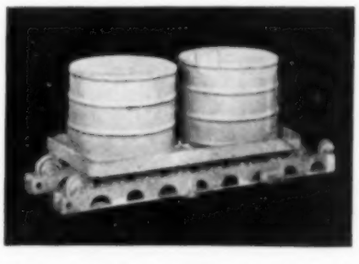


A HYRO furnace was exhibited at the Chicago Show equipped with Q-Alloy pot.

You can now buy . . .

. . . our Carburizing Containers in our own and other established analyses at the same prices that all other makers charge for alloys having the same Nickel-Chromium content . . . . *but lacking the engineering, foundry practice and service of The General Alloys Company* . . here's where you get a break. Sheet boxes or cast boxes.

How About a Few New Hearth Plates?



Heat Resisting Alloys In the Steel Mill...

We of the General Alloys Co. have been watching history repeat itself in the application of alloys to the steel industry.

Most of the mistakes incident to the introduction of heat resisting alloys into the automobile industry (for instance) are being repeated,—and plus a lot of older,—and newer ones.

The steel mill alloy applications run into large tonnage, bought largely by price buyers from price sellers. Such a "market" attracted a few low grade alloy makers and some steel foundries, steel molding practice being considered the least exacting in the entire metal molding trades.

Such foundries, innocent of the arts of the alloy maker, engaged specialists, made trial installations,—and published gobs of "technical data" that some people—and worst of all in some instances—they themselves believed.

Alloys were often sold on entirely experimental jobs under ridiculous guarantees. The older types of steel mill furnaces generally had two temperature limitations, viz.,—first the melting point of the steel and second, if the steel was moving fast enough, the melting point of the brick.

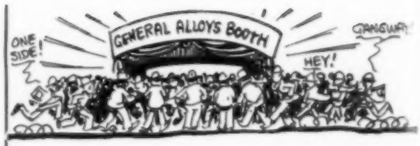
Base product producers, "hell for leather" equipment riders, the steel industry has been largely educated to price buying of heavy "Polack proof" equipment. Few mill men looked ahead beyond the orders on hand. Fewer brought painstaking analysis to bear on the mills' heating problems in the light of modern heat treating furnace development.

Furnace builders toyed hesitatingly with the mill furnace market—held back for good reasons—viz., good business in other lines and antipathy to missionary work, converting price buyers to economic reason—the magnitude of the task—greater risks on larger furnaces at higher temperatures—above all terrific sales resistance.

We as alloy makers, with a reserved seat, reserved by our qualifications to render intelligent service, stood by to let others in their ignorance or enthusiasm make ridiculous guarantees on highly experimental apparatus operated under devious conditions in furnaces generally experimental, usually semi-modern, by men inexperienced in temperature control, operating with insufficient control equipment under management inherently hostile to progress.

There has been a lot of history repeated—the old struggle of brains versus brawn in industrial progress—a lot of alloy scrapped—lessons learned. We too have learned by watching and waiting. Now we believe the steel mill is thoroughly awake, grasps for the best the furnace engineer can offer,—the best alloys man can make,—ripe for the experience that an alloy engineering organization, incidentally foundrymen and fabricators, has gained in twelve years designing and manufacturing 130,000 different designs in heat resisting alloys. This experience covers the bulk of modern furnace mechanisms installed by leading heat treating furnace builders.

Our experience without that of the practical mill man would be of little value. We strive to cooperate for mutual benefit. H. H. H.



The General Alloys booth at the Steel Show easily contained more individual exhibits than all other alloy exhibits combined. In carburizing boxes we had everything from sheet boxes with and without cast bottoms, with and without cast corners, to solid cast boxes and super-thin boxes made out of cast sides and bottoms $\frac{3}{16}$" thick welded together at the corners. Not so good, but somebody may like it.

Counterflow furnace rails as supplied to Electric Furnace Co., Surface Combustion Co., George J. Hagan Co., W. S. Rockwell Co., Holcroft & Co., etc., were set up with standard types of grids and various types of boxes. Carburizing boxes with 10,000 to 16,000 hours service were exhibited in excellent condition.

Always original, our souvenior this year was a vitreous enameled ash tray on which the visitor wrote his signature before the second firing. The trays were fired at night and returned the next day. This one was autographed by one of our Russian visitors.

A display board showing 48 standard sizes in that many designs of Link-Belt Q-Alloy chain was shown. The famous Q-Alloy clock movement made entirely of Q-Alloy which kept time at 2000° at the Philadelphia Show, as well as the bas-relief of Abe Lincoln, was among the exhibits. Fans and fixtures for L & N HUMP furnaces were shown, and over 300 miscellaneous items . . . We try to make our exhibit of educational value to the trade, not merely a sign and a sofa.

WILLIAM T. YETMAN
COMMENTS ON BUSINESS

Ed. note.—Wm. T. Yetman, head of Yetman's Statistical Service, of Boston, is a recognized authority on economics and markets. He is a director in leading investment trusts, and supplies leading brokers with data in weekly market letters. Mr. Yetman is handicapped in preparing an article going to press Oct. 6th for Nov. 1st publication, and we can place only very limited space at his disposal, which prevents detailed analysis of the many factors affecting business.

Nearly five hundred of our readers have asked for business comment. We would appreciate letters commenting on Mr. Yetman's article. "Don't put any sugar coating on the pill," we told Bill in wiring for this article, "we are not running for anything on the Republican ticket and we want the lowdown."

The Business Situation

GENERALLY speaking, September records of industrial activity have been distinctly disappointing to those who were expecting substantial improvement. Latest indications are that a few lines showed betterment of nearly seasonal proportions, but that the more important and basic industries failed to show appreciable gain. While October, which is theoretically the peak month of activity in many lines, may effect some encouragement, it does not appear likely that sustained improvement will be evident before next year.

One bright spot has just appeared, namely, a break in the steady decline of electric power production. This index for the final week of September, although still 3.2% under a year ago, showed an increase over the preceding week of slightly more than seasonal proportions. This rate of gain, if maintained through October, would be indicative of an encouraging increase in industrial activity.

The Motor Industry

A COMPARISON of the present position of the automobile industry with the conditions existing during the first half of 1929 must be considered from two different angles.

First comes the generally recognized change from prosperity to depression. This phase of the changed conditions leads to consideration of the second phase, which, after all, is the more important one. Last year the industry was producing cars faster than they could be sold, and it was only a question of time before the inventories would become unwieldly. This year has seen a reversal of these conditions, with the result that since the end of April there has been a reduction of over 200,000 in the inventories of new cars.

Registration of new passenger cars in August, based on complete returns from 30 States, were off 49.6% from August last year. Production of passenger cars during that month showed a reduction of 57.5% compared with the same month a year ago. For the first eight months of the current year, estimated registrations indicate a 29% drop from those of the similar 1929 period, while output showed a decline of 36%.

The above figures indicate that the determined efforts of producers to keep output in line with demand have been successful. Dealers' stocks, therefore, have not only shown no increase, but are believed to be at or close to their lowest point in about two years.

While also affected by the business depression, the truck division of the industry has shown somewhat less drastic curtailment than the passenger-car department. Production of trucks in August was approximately 37% under that of August last year, and for first eight months was 32% less than during the corresponding period a year ago. It is also noted that the number of trucks produced in the first two-thirds of the current year was nearly 10% greater than in the like period of 1928, whereas passenger-car output for that period showed a drop of almost 14.5% from 1928.

At present, the automotive industry is operating at a rate only moderately above the low level of late July and early August. Although no material increase in activity is expected for the balance of 1930, the comparatively favorable statistical position of the industry suggests the possibility of appreciable improvement when the general business situation shows definite signs of sustained recovery.

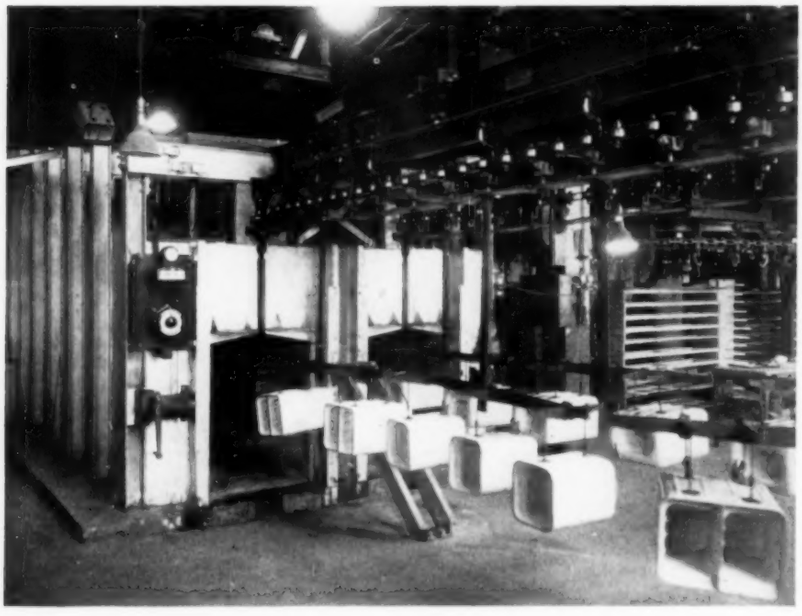
Outlook for the truck division of the motor industry is believed to be steadily improving. United Business Publishers estimate that sales of trucks in October will be slightly better than last month and about 10% less than in October, 1929. Prospects for next year are encouraging.

The Steel Industry

THERE has been reported a moderate increase in steel buying during the past month. Production has also been at a higher rate in recent weeks, although the gain has been somewhat less than seasonal. The price situation has displayed a slightly firmer tone resulting in a growing interest in forward buying. In view of the fact that automobile requirments and rail orders are expected to be lower than in recent years, little evidence exists to indicate anything better than seasonal recovery in the steel industry for the remainder of 1930. A sustained improvement in the steel situation is entirely dependent upon the proximity of genuine recovery in business conditions.

—Wm. T. Yetman.

WESTINGHOUSE



AN UNUSUAL VITREOUS ENAMELING INSTALLATION

Because of the exacting requirements under varied conditions in the Enameling Industry there has been an outstanding need for more efficient furnace equipment. The Westinghouse Company has pioneered and developed the continuous electric enameling furnace, which has proven a decided contribution to the Industry.

One of the Westinghouse recent installations is at its Mansfield, Ohio, plant used in firing refrigerator evaporators. This application is considered one of the most difficult, due to the construction of the evaporator. The evaporator is made up of an inner shell around which is brazed a coiled copper tubing and the outer shell is welded to the inner shell at the front edges. This construction because of the heavy mass with air pockets in between and welded sections presents an enameling problem which necessitates very exacting conditions. Before the installation of the furnace it was determined that the evaporators had to be heated up very uniformly, and slowly, also that the temperature gradient between the heating elements and the firing chamber had to be extremely close. It was also determined the cooling of the evaporators had to be effected slowly. All of these exacting conditions have been met with entire satisfaction.

This installation consists of a Horseshoe type continuous furnace with overhead conveyor and elevated firing chamber. The furnace is 51 feet long and the mean diameter of the firing chamber is 4 feet. The rating of the furnace is 400 KW. and is divided into four zones of 100 KW. each for flexibility, the heating elements being located in the semi-circular end of the furnace.

Production output of this furnace is approximately 6800 pounds gross per hour.

The firing chamber is elevated to form a partial heat seal, and in addition the furnace is equipped with the Westinghouse patented air curtain seal near the open end of the furnace, which effects considerable additional economies. The air curtain seal is accomplished by means of two blower sets operating in parallel located near the charging and exit end of the furnace, the air being drawn out at the bottom of the furnace and circulated back in at the top of the furnace.

Another outstanding feature of this furnace and other Westinghouse designs is the method in which the slotted or overhanging roof is supported. Each of the fire brick tile is supported near the slot by means of an alloy bolt anchored to the frame construction on the top of the furnace, and just ahead of the adjusting nut is a heavy coiled spring which allows without injury full expansion and contraction of the furnace roof. This method of supporting an overhanging roof has not only proven entirely satisfacory, but also allows making the slot in the furnace roof very narrow, which in turn reduces the heat losses, thus increasing the efficiency of the furnace.

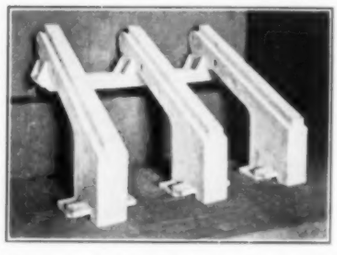
The loading tools for supporting the evaporators through the furnace are of high grade heat resisting alloy, and consist of load bars suspended from vertical rods attached to the conveyor chain. In addition there are tools similar in shape to coat hangers, which are placed crosswise on the loads from which the evaporators are supported by means of hooks. All of the alloy tool equipment on this installation was supplied by the General Alloy Company of Boston, Mass.

Miscellaneous

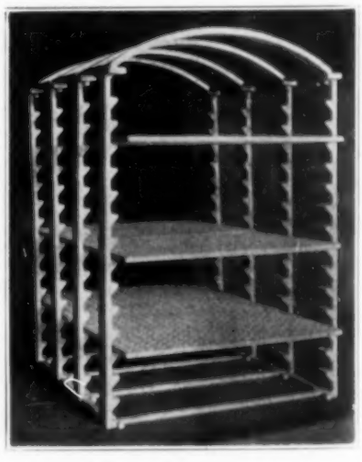
IF you had some light work that you wanted to get in and out of a furnace quickly and heat it rapidly you might use a little buggy like this for the hot babies—

OR if you wanted to put the skids under a few billets, axles or forgings what could be neater than something like this staunch trio of Q-Alloy guides—

THEN perhaps you could get better combustion if your burner assemblies were free from oxidation, insuring correct distribution. Why not use Q-Alloys for the hot burner parts?



LOOK around the heat treat a little further and see if you couldn't greatly increase your furnace capacity and get more small work heated quicker by multiple decking the furnace with Q-Alloy racks on the order of these shown, or probably you have a much better idea yourself.



AFTER all you probably don't need any of these gadgets shown above, but while your mind is working on the subject of miscellaneous alloy applications you can probably think up several ways that properly designed Q-Alloy parts, fixtures or mechanisms can save you money and facilitate production. Our engineers will be glad to help if you look like a possible prospect, preferably by dropping us a line.

ALLOYS PROGRESS PAGE X

Non Burning Char Compound does not continue to burn when discharged into the air from carburizing temperatures.

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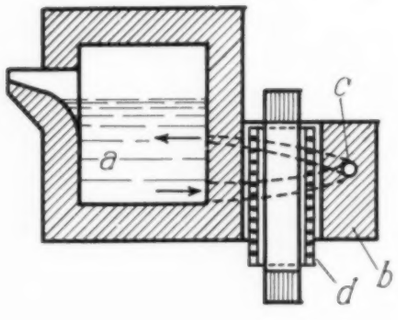
Reviews of Recent Patents

by Nelson Littell

Patent Attorney 475 Fifth Avenue, New York Member of A.S.S.T.

Induction Furnace, *by E. F. Russ, of Cologne, Germany. 1,770,662; July 15.*

An induction furnace with closed melting channels is covered. The patent describes a form which permits a vigorous flow of the stream of molten metal in order to obtain thorough mixing thereof and to prevent local overheating in the narrow melting channel, which has been substantially impossible when melting such metals as copper and bronze, which are very sluggish in the liquid condition. In the figure it will be noted that the hearth chamber *a* has an addition *b* to one side, and slightly lower than the chamber *a*. A melting channel *c* is arranged so that it surrounds the primary winding *d* and



opens into the melting chamber *a* with its ends at different heights. Consequently the repulsion of the primary coil acts in the whole channel from its lower inlet opening to its upper outlet opening as an upwardly driving force. The thermodynamic action acts in the same way over the whole channel. In order to maintain the frictional resistance and the cooling surface of the channel as small as possible it may be formed of circular or oval cross-section.

Inhibitor, *by Ira Williams, assigned to Grasselli Chemical Co., Cleveland. 1,773,247; Aug. 19.*

Aldehydes have been suggested for inhibitors in the process of cleaning and pickling metal surfaces, but as unpleasant odors are generated they are most obnoxious to the workmen. The present patent describes the use of acrolein derivatives in which the alpha and beta carbon atoms are substituted by hydrocarbon radicals. One of the inhibitors is a dilute mineral acid containing a small amount of alpha-ethyl beta-propyl acrolein. Only a small amount of the inhibitor need be used, as in pickling approximately 140 tons of steel and iron stock it was only necessary to use 51 lb. of the inhibitor with 52,000 lb. sulphuric acid.

Manufacture of Magnetic Alloys, *by V. B. Browne, of Brackenridge, Pa. Re-issue 17,771; registered Aug. 12.*

A reissue of original patent No. 1,570,229 for manufacturing silicon iron or steel, now largely used as a magnetic alloy. The method broadly consists in refining molten iron in a furnace and in removing as much carbon as is possible by standard methods, then in passing air through the molten iron until all traces of carbon are removed, and then in adding the desired amount of silicon to the carbon-free iron. It is possible to utilize either an open-hearth or an electric furnace, and silicon iron can be produced having carbon less than 0.03% and silicon as high as 5%.

Arc Welding, *by J. F. Lincoln, assignor to Lincoln Electric Co., Cleveland. 1,774,023; Aug. 26.*

Patentee describes a process wherein the electric arc is struck between the parts to be fused and a carbon electrode that is moved relatively to such parts so as to cause the arc to traverse the work. The object is to overcome the lag or "stick" as well as the tendency of the arc to shift irregularly from one point to another on the work. By establishing an arc between the work and a suitable electrode and then relatively moving such work and electrode to cause the latter to follow the line to be welded and surround such arc with a closed circuit for flux set up by the flow of current through such arc, it will be found that the objectionable features of other methods will be avoided.

(Continued on page 136)

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• NEW IDEAS and interesting facts! One important thought from us, we hope:

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Not only does the patented atmosphere control of the Hayes Certain Curtain Furnace successfully lead to the ideal grain structure, but it also eliminates all common surface defects such as pitting, scaling, soft surface, etc. Read the booklet. It may mean thousands to your firm.

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I will appreciate receiving a free copy of Sam Tour's booklet.

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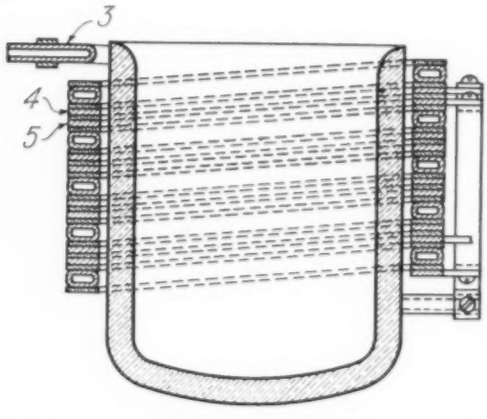
Induction Furnace, *by G. B. Tjoflat, assignor to Westinghouse Electric & Mfg. Co. 1,763,200; June 10.*

This invention particularly discloses an artificially cooled induction coil which is simple in construction, easily manufactured and having an improved space factor as compared with other artificially cooled coils. As shown in the figure a coil *3* of hollow section through which cooling fluid such as water may circulate, has a number of turns spaced from each other by coils *4* and *5* of solid section. All coils are insulated from each other by mica. After the coils have been wound together they may be compressed so that the respective turns are in good thermal communication with each other, and as the coils



4 and *5* are solid and rectangular they may be made of such dimension that they will carry a maximum of current with a minimum I^2R loss. The coil *3* may be so shaped that the two faces thereof are of substantially the same width as the conductors constituting the coils *4* and *5*. With such a construction it is found that the number of ampere turns per unit of axial length of coil may be increased to a value heretofore unknown.

Manufacture of Silicon Steel, *by W. J. Woolridge, of Mansfield, Ohio. 1,773,157; Aug. 19.*

A process for the manufacture of silicon steel plates for electrical apparatus such as reactors and transformers. The invention has for its object to reduce the scale which forms on silicon steel and to provide plates which have the properties of well annealed steel. Pickling is unsatisfactory, because in the case of silicon steel the surface *(Continued on p. 138)*

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quality is not primarily important. Patentee first rolls the plates hot and then in cold rolls, after which they are annealed at the usual temperature. The re-annealing is at a temperature not substantially greater than 300° C.

Process of Cleaning Metal, *by H. P. Corson and R. E. Lawrence, assignors to Grasselli Chemical Co., of Cleveland. 1,773,953; Aug. 26.* Relates to cleaning processes in which an inhibitor is used to prevent undue action between acid and metal. The particular inhibitor is natural and synthetic ichthyol products. They have a marked property of inhibiting the action of non-oxidizing acids and yet do not effect the dissolution by the acid of oxides, and other undesirable incrustations. The active pickling and cleaning ingredient is a non-oxidizing acid to which is added an inhibitor comprising a sulphonation product of a mineral oil, which contains in the neighborhood of 10% or more total sulphur, part of which is in the form of sulphones, and which in its general properties is identical with or similar to ichthyol.

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Ferro-Titanium	25%
Ferro-Vanadium	35-40%
(1% Silicon)	

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Ascoloy 44—Allegheny Steel Co. A technical bulletin describing this high-heat resisting chromium alloy will be sent on request. Ask for bulletin No. C-3.

Micro-Objectives etc.—E. Leitz, Inc. In this publication are described micro-objectives, oculars, summars and micro-summars, covering the most extensive assortment of optical units for metallographic studies. Ask for bulletin No. C-4.

Heat Treating Furnaces—W. S. Rockwell Co. Catalog covering Rockwell heat treating furnaces, car and car and roll type, electric or fuel. For heating large and irregular shapes or forgings, also in pots and boxes. Ask for bulletin No. C-5.

Ingot Molds—Gathmann Engineering Co. A new book covering the subject of ingot molding. It contains numerous illustrations of the effects of various methods of finishing and casting on the reliability of steel products. Booklet C-1.

Hardness Testers—Wilson-Maeulen Co. A booklet illustrating a number of practical applications of the Rockwell hardness tester to inspection production testing. Booklet C-2.

Tool Steels—Carpenter Steel Co. Bulletin "Timbre and How It Affects the Properties of Carbon Tool Steel." Defines Timbre and illustrates and describes Timbre testing. Published by the research department. Bulletin C-6.

Mayari Steels—Bethlehem Steel Co., has issued a folder on Mayari Nickel-Chromium Steels. These steels possess unusually high fatigue-resistance and endurance, and stand up under severe shocks and dynamic stresses. Ask for bulletin No. B-1.

Testing Machines—Pittsburgh Instrument and Machine Co. New catalog describing Brinell machines and accessories. Also "Diamo-Brinell" type, a direct-reading Brinell tester using either 1 millimeter diamond or 2 millimeter steel ball. Ask for bulletin No. B-2.

Corrosion and Heat Resisting Steels—Colonial Steel Co., Vanadium Alloys Steel Co., and Anchor Drawn Steel Co. Booklet gives complete data regarding stainless A, stainless B, stainless I, stainless FMS, stainless N, stainless U and stainless CNC. It is intended for shop men to whom it gives valuable technical information. Ask for bulletin No. B-4.

Die Blocks—Heppenstall Co. Booklet of 50 pages on various Heppenstall die blocks. Booklet also contains metallurgical engineering data, tables of weights of materials, temperature conversion, mensuration formulae, etc. Ask for bulletin No. B-5.

Deoxidizers—Vanadium Corp. of America. Leaflet describing Alsifer, a material used for the deoxidation of steel during manufacture. Ask for bulletin No. B-6.

Pot Furnaces—Hyro Mfg. Co. Booklet describes new Hyro pot furnaces for case hardening by cyanide and other salts, heat treating, etc. This new furnace makes certain kinds of heat treating safer and more efficient. Ask for bulletin B-8.

Furnaces—American Gas Furnace Co. "Furnaces for Various Heat Treatments," a discussion of the requirements in hardening high speed steel with reference to furnace equipment, also an outline of various heating machines and a description of rotary retort machines for carburizing. Ask for bulletin No. B-9.

Nickel Steel—International Nickel Co. Data and Applications. A series of 17, 8½ by 11 inch semi-technical bulletins with convenient loose leaf type binder to facilitate filing and increase their reference value. Ask for Bulletin B-11.

Heat Treating Chemicals—Roessler and Hasslacher Chemical Co. Booklet "Case Hardening and Heat Treatment of Steel." Comprehensive data on cyanides for surface hardening, physical properties and methods of use of salt baths for drawing, annealing and general hardening. Ask for bulletin No. B-13.

Fuel Fired Furnaces—Electric Furnace Co. Eight-page bulletin illustrating oil and gas fired continuous and batch type billet heating, forging and car type furnaces for heating, normalizing and heat treating, also labor saving material handling equipment. Ask for bulletin No. B-18.

Nirosta Buyers Guide—Krupp Nirosta Co. Inc. A concise listing of Companies producing Nirosta metal, their addresses and the forms of material they are prepared to furnish. Ask for bulletin No. B-19.

Furnaces—Strong, Carlisle and Hammond Co. invites your requests for their bulletins and reprints of recent furnace installations. Your inquiries are solicited. Ask for bulletin No. B-20.

Nitriding—Hevi Duty Electric Co. has just published a new bulletin "Essentials of Successful Nitriding," giving a description of the elements of successful nitriding given in light of the company's research, in the laboratory and in regular production. Ask for bulletin No. 22.

Potentiometers—Thwing Instrument Co. "The Treasure Chest" is a highly accurate portable potentiometer, a laboratory in itself, completely self contained with standard cell, batteries, resistance coils, self checking feature, stations for checking thermocouples and for reading temperatures from thermocouples. Ask for bulletin No. B-23.

Slushing Compound—The Skybryte Co. Steelbrite is an entirely different rust preventing compound from ordinary oils and greases. It has none of their objectionable features and gives greater protection to sheet and strip steel and fabricated parts. Ask for bulletin No. B-24.

Industrial Regulators—Minneapolis - Honeywell Regulator Co. Booklet

Metal Progress, 7016 Euclid Ave., Cleveland.

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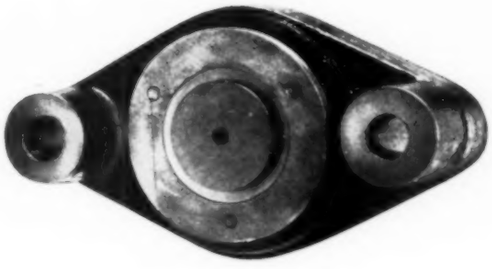

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Helpful Literature Continued.

describing their motorized valves used in furnace temperature regulation. These valves operate with their regulators or with any pyrometric controller to regulate flow of gas, oil and air. Ask for Bulletin No. A-2.

Resistance Thermometers—Leeds and Northrup Co. Revised catalog treating in detail resistance thermometers for recording, controlling and indicating temperatures, covering heating and ventilating, applications in refrigeration and chemical plants, gas-making and other low temperature applications. Ask for Bulletin No. A-3.

Steel Refining—Densite Corp. of America. A folder in the form of a chart showing physical properties and photomicrographs of structures and inclusions of various carbon steels refined with Densite. Chart is of especial interest to metallurgists and heat treaters. Ask for Bulletin No. A-5.

Gas Heat—American Gas Association. A text-book on the uses of gas in industry, giving comprehensive data on industrial gas heat. Illustrated. Free. Ask for bulletin No. A-7.

Steel Handbook—Jos. T. Ryerson & Sons, Inc. Handbook on Tool and Alloy Steels. Description, technical data and general information on tool and alloy steels. Also nontechnical description of heat treating methods and shop practice applying to various steels. Ask for bulletin No. A-8.

Induction Furnaces—Ajax Electrothermic Corp. This bulletin gives latest information regarding coreless induction furnaces in capacities up to several tons, and motor-generator equipments for energizing the furnaces. Ask for bulletin No. A-9.

Corrosion Prevention — Dearborn Chemical Co. Booklet describing latest scientific methods of treating water for prevention of scale, corrosion and foaming in steam boilers, dealing with related problems in connection with scale and corrosion in other power plant equipment. Ask for bulletin No. A-10.

Heat Resisting Steels — Midvale Co. Booklet is largely a diagrammatic classification showing the content of the various alloys. It was produced because of a large number of requests for exactly this type of information. Ask for bulletin No. A-11.

Special Analysis Steels — Wheelock, Lovejoy & Co. Folders give analyses. Hy-Ten steel ranges in carbon from .10 to 1.00 per cent. There is a Ty-Ten grade for every vital machine part. Ask for Bulletin No. A-12.

Tool Steel Handbook — Columbia Tool Steel Co. Booklet contains valuable information concerning the making of tools, heat treating, application of steels, with tables, etc. gratis. Ask for Bulletin No. A-13.

Heat Resisting Alloys — General Alloys Co. General catalog on Q-Alloys, which has recently been prepared describing many applications of heat resisting alloys. Ask for Bulletin No. A-15.

Pickling Equipment — Weaver Bros. Co. Catalog listing equipment and supplies now available. Depicts all necessary equipment and has new "theory and practice of pickling." Ask for bulletin No. A-17.

Stainless Irons — Republic Steel Corp. Series of booklets descriptive of Enduro Stainless Irons. Each booklet is devoted to a single type of stainless and contains complete fabrication data, and descriptions of the physical and chemical properties. Ask for bulletin No. A-19.

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THERE is no cure-all in steel. Different alloys suit different purposes. But Midvaloy H R does fit a surprising number of needs. Its heat-resistant and corrosion-resistant qualities make it both efficient and economical for high temperature operating conditions. Successful installations with Midvaloy H R include: continuous furnace parts, retorts, boxes, recuperator tubes, stoker grates, tuyeres, chains, slicing links, sulphide roasting furnace parts, oil refining furnace parts, cast pyrometer tubes and gas industry equipment.

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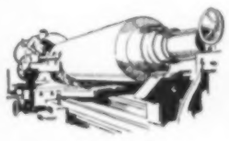


TOOL STEEL

Midvale does not follow the "tonnage" method of tool steel production. Midvale charges with cold metal. Lets the ingots cool, to permit inspection for faults. Carefully chips out any cracks. Reheats ingots and reduces to billet size. Sand-blasts the scale. Again inspects and chips when necessary. Reheats and rolls to finished size. This is the only method by which tool steel of Midvale quality can be produced.

FORGINGS

Midvale is a "custom shop"— where practically every forging and casting problem a steel man can meet has been met. Midvale melters, forgers, heat-treaters are men experienced in producing those forgings where every square inch of cross-section must do its full duty.

The Engineering Index

REGISTERED UNITED STATES, GREAT BRITAIN AND CANADA

In the preparation of the Engineering Index by the staff of the American Society of Mechanical Engineers some 1700 domestic and foreign technical publications are regularly searched. From this material the A.S.S.T. is supplied with this selective index to those articles which deal particularly with steel treating and related subjects.

ALUMINUM METALLURGY

Incrudescence, Rolling and Annealing of Pure Aluminum (Incrudimento, laminazione e ricottura dell'alluminio puro), P. Tucci. *La Metallurgia Italiana (Milan)*, vol. 22, no. 7, May 1930, pp. 561-570, 11 figs.

Report on experimental study made at Royal School of Engineering of Turin for determination of changes in mechanical characteristics of pure commercial aluminum as function of incrudescence and annealing temperatures; optimum rolling and annealing conditions.

Anodic Protective Treatment of Aluminum And Its Alloys (Die anodische Schutzbehandlung von Aluminum und seinen Legierungen), M. Haas and E. Weitz. *Korrosion und Metallschutz (Berlin)*, vol. 6, no. 6, June 1930, pp. 121-127, 18 figs.

Critical analysis of anodic oxidation process of Bengough and his co-workers; tests were carried out on duralumin, lautal, aludur, and alpax; results show that Bengough process can be successfully applied to these light alloys.

CASE HARDENING

AMMONIUM FORMATE. Surface Hardening Particularly by Use of Ammonium Formate (Oberflaechen-Verstaehlung, insbesondere durch Ammoniumformiat-Streu- und Tauch-Verfahren), H. Reininger. *Werkzeugmaschine (Berlin)*, vol. 34, no. 6, Mar. 30, 1930, pp. 133-141, 25 figs.

Review of fundamental principles of surface hardening, advantages of ammonium formate are discussed and compared to other materials; chemical and thermal preparation of parts to be treated with ammonium formate.

CYANIDE BATH. Hardening Steel Commercially by Cyaniding Process, E. F. Davis. *Steel*, vol. 87, nos. 3, 5, and 7, July 17, 1930, pp. 43-46 and 60, July 31, pp. 47-48 and 53, Aug. 14, pp. 48, 50, and 52, 17 figs.

July 17: Outline of history of cyanide, properties and advantages of various grades, and mechanism of hardening process, July 31: Discussion of brittleness of cyanided steels and its relation to cyaniding temperature and quenching methods, cyaniding gears and wire; various advantages and disadvantages of cyaniding as a hardening process. Aug. 14: Description of furnaces and pots for cyaniding, aerocase method, fume prevention, cyanide poisoning and testing cyanide baths.

ELECTRIC MELTING

MELTING. Melts Iron and Steel in Electric Furnace, G. S. Scaller. *Foundry*, vol. 58, no. 16, Aug. 15, 1930, pp. 48-51, 10 figs.

Layout and operations at Lidgerwood Pacific Co. plant, Tacoma, Wash., average power consumption per ton of iron melted is 544 kw-hr. at rate that varied from 0.7 to 1.02 cents per kw-hr.; notes on physical properties of melted iron and steel; data on operation of electric furnaces over period of two years.

MELTING. Electric Furnace Iron—A statement of the Present Status, G. L. Simpson. *Iron and Steel of Canada (Gardenvale, Que.)*, vol. 13, no. 8, Aug. 1930, pp. 170-171 and 173.

Abstract of article previously indexed from Am. Electrochem. Soc.—Advance Paper, no. 57-12, for mtg. May 29-31, 1930.

FORGINGS

NICKEL ALLOY. Nickel Alloy Steel Forgings, C. McKnight. *Am. Soc. for Steel Treating—Trans.*, vol. 18, no. 2, Aug. 1930, pp. 129-140 and (discussion) 140-146, 5 figs.

Large forgings constitute important and constantly increasing field for alloy steel; data published by Society of Automotive Engineers on properties, analysis and heat treatments of alloy steel are standard, but not applicable to large forgings as based on tests made on one inch bars; paper deals briefly with manufacture, uses, analysis, heat treatment and properties of nickel alloy steel forgings larger than four inches in diameter or equivalent section.

STEEL. The Effect of Reduction From Ingot to Forging in Steel Forgings, L. H. Fry. *Am. Soc. Testing Matls.—Proc.*, vol. 29, part 2, 1929, pp. 170-180 and (discussion) 181-182, 3 figs.

FORGINGS. The Manufacture of Die Blocks, J. P. Bindyke. *Heat Treating and Forging*, vol. 16, no. 7, July 1930, pp. 864-868 and 880, 7 figs.

Description of manufacturing process of Heppenstall Co., following steel from open-hearth furnace to and through forge shop and heat treating departments; notes on inspection and testing of die blocks; chemical composition and physical property values are given.

FORGING. Construction of Dies for Forging, A. Allen. *Heat Treating and Forgings*, vol. 16, no. 7, July 1930, pp. 861-863, 6 figs.

Discussion of design and heat treatment of dies for various types of forgings notes on life of dies and split dies.

FORGING. Tentative Specifications for Carbon-Steel Forgings for Locomotives. *Am. Soc. Testing Matls.—Proc.*, part 1, vol. 29, 1929, pp. 555-560, 1 fig.

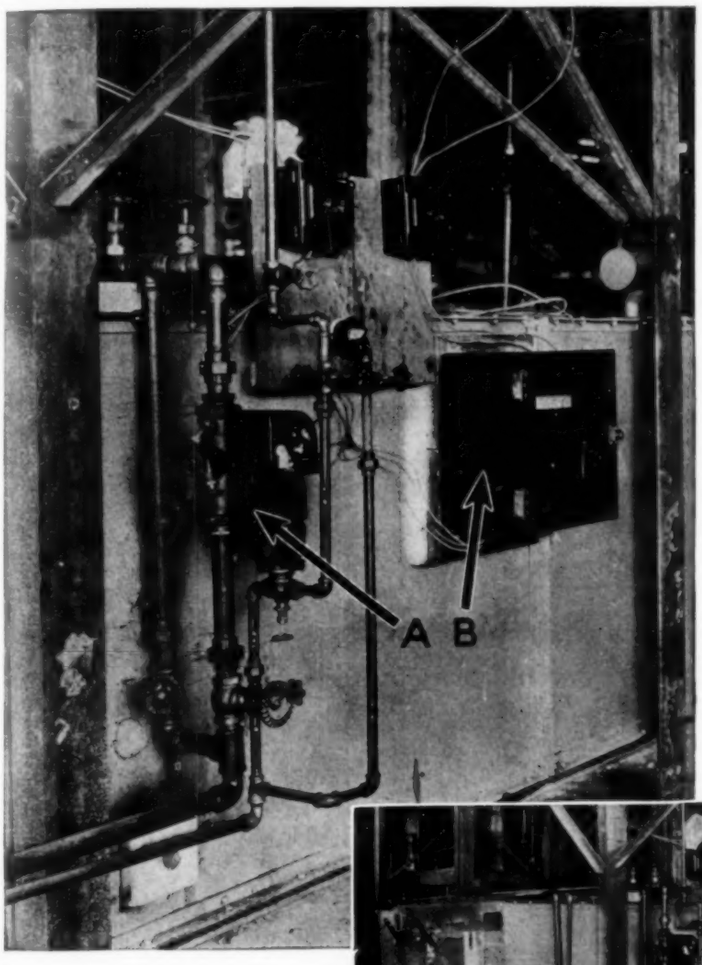
These specifications cover untreated, annealed, and normalized and tempered carbon-steel driving axles, engine and trailing truck axles, main and side rods, straps, crank pins, piston rods, and annealed car and tender axles.

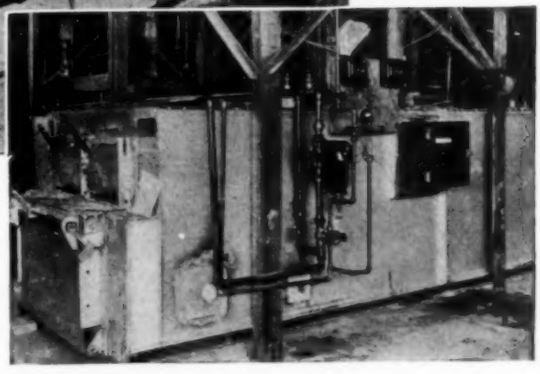
(Continued on page 170)

THE ATTENTION *of* FORWARD-MINDED MEN IN INDUSTRY

C E N T E R S U P O N

AUTOMATIC CONTROL





Above: Bristol's Pyrometer Controller and Bristol's Motor Operated Controller Valves. (A) shows Controller Valve; suggesting simple, convenient piping arrangement. (B) is Model 479 Pyrometer Controller mounted in new style all-metal protection case.

PRESENT DAY demands for greater operating economy and all-round high efficiency has caused attention to be centered more and more upon the "Automatic Control" factor in production. This is particularly true where such control is applied to heat processing . . . where successful operation necessitates the maintenance of constantly uniform temperatures. ⋆ The answer to many of these temperature control situations can be found in the very complete line of Bristol's Control Equipment . . . available for use in connection with oil, gas or electrical heated furnaces, ovens, etc., to operate within selected control ranges up to 3000° F. ⋆ Reliability and accuracy have been thoroughly tested on thousands of industrial control jobs. Design throughout is simple, and construction sufficiently rugged to assure continued accuracy and trouble-free operation for years under all ordinary service conditions. ⋆ Get complete details! Catalogs, bulletins will be sent to any interested person in your plant. Write direct to *The Bristol Company,* Waterbury, Conn., or to the nearest branch office.

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Instruments *for* Indicating Recording Controlling

The R-101 (Continued)

and a third series of girders forming an inner polygon about 25 ft. smaller diameter tied to it by intermediate radial struts and cross braced with short wires. Two members of the inner polygon cross the upper left corner of the view. All members were pin connected to aluminum die castings at the intersections. The workman in the left center of the photograph on page 98 is standing near such a connection.

The three booms of each of these girders were made of stainless steel strip bent into tubular form, the edges flared back out for riveting to duralumin webs, the latter pierced with flanged lightening holes.

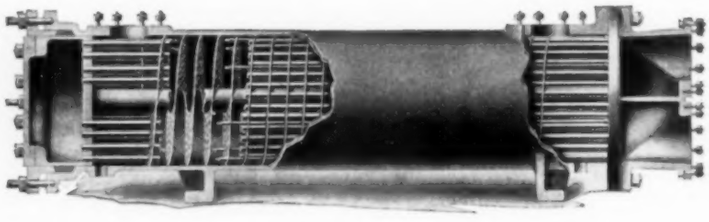
Main longitudinal girders, while of triangular cross section, were of different construction. The three booms were of stainless steel strip closed into a tube by an inner lock joint. They had tubular struts between booms and swaged rods for cross bracing in the three planes, all connected together by stampings, properly drilled, fitted and riveted. The workman already mentioned is standing on one of the booms of a main longitudinal girder which extends across the view from left to right. The other man is standing on a cat walk leading up to fuel tanks placed within the frame. (It appears at the top left corner of the view.) This wedge-shaped volume at each of the main frame was kept open for such storage purposes, for necessary piping, and for inspection.

Tube Making Methods

The method of manufacturing the stainless steel tubes, as worked out by Boulton & Paul, is very interesting. Flat strip, in softened condition was drawn through a series of dies gradually bending it up edgewise, and finally over a locking mandrel. Heat treatment then followed by drawing the formed tube slowly through a wire wound furnace, bringing it to temperature, then out in air through a long enough space to cool it past the critical, then through a water cooled die to complete the chill. A die at the entrance

(Continued on page 166)

G-R Quenching Oil Coolers



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This is only one of the many advantages of this revolutionary advance in hardening equipment. Some of the other important ones are: (1) The Hyro Automatic is safe . . . does away with all usual dangers . . . vastly improves working conditions. Result: Fire and compensation insurance premiums are greatly reduced; labor turnover is practically eliminated. (2) One man can tend two—or even more—Hyro units more easily than he can a single old-style pot furnace. Result: The Hyro Automatic cuts labor costs. The illustration below will make these and the other advantages clear.

It's easy to harden one piece of steel to a predetermined degree. The trick is to harden a hundred, a thousand, a million . . . uniformly, day after day, month after month. Ordinary pot furnaces won't do it . . . but the Hyro Automatic will! So it will pay you to send in the coupon below and get all the facts.

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1 Hood-enclosed pot furnace. Has Pyrex window for observation of work while in process. All fumes go up the flue.

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3 Quenching tank, fully enclosed. Covered by a baffle plate to "break up" work and prevent back-splash. Hood opens above into an exhaust pipe.

4 Hand-wheel which empties quenching tank basket into hopper. Counterbalanced and self-locking.

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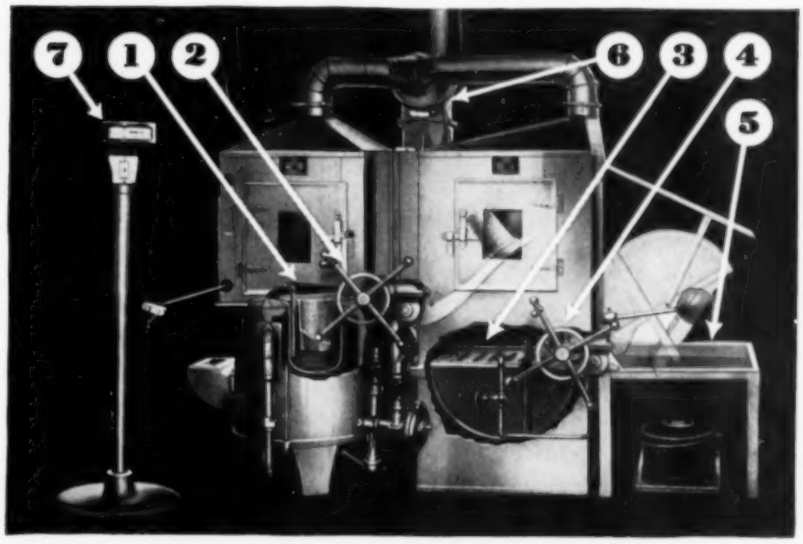
11-30



HYRO AUTOMATIC FURNACE

For Case Hardening and Tempering

IRON

On the Road to Pure Iron and Some of Its Indicated Properties, T. D. Yensen. *Am. Electrochem. Soc.—Trans.*, vol. 56, for mtg., Sept. 19-21, 1929, pp. 215-223 and (discussion) 223-229, 2 figs.

By careful preparation, using electrolytic iron with small amount of carbon as deoxidizer, and vacuum furnaces, samples have been obtained with greatly improved magnetic properties, indicating that pure iron may have hysteresis loss approaching zero, and very high permeability.

Recent Developments in the Analysis of Carbon in Iron and Iron Alloys, N. A. Ziegler. *Am. Electrochem. Soc.—Trans.*, vol. 56, for mtg., Sept. 19-21, 1929, p. 231-8.

Modifications and improvements in Yensen method for accurate determination of carbon in iron and iron alloys are described.

STEEL HEAT TREATMENT

The Effect of the Rate of Cooling on Steel, J. M. Robertson. *Chem. Age (Lond.)*, vol. 23, no. 575, July 5, 1930, (Met. Sec.) pp. 1-2.

Discussion of accepted theories of effect of heat treatment on steel; original theory of relations of martensite, troostite, and sorbite to each other and to normal iron-carbon diagram; four series of structures obtained by different methods of cooling.

The Sandberg Sorbitic Steel Process. *Metallurgia (Lond.)*, vol. 1, no. 5, Mar. 1930, pp. 205-206 and 214, 7 figs.

Physical variations in steel are fundamentally due to influence of chemical composition and heat-treatment; in this article heat-treatment is considered.

HEAT TREATMENT. Heat Treatment of Extra Mild Steel (Il trattamento termico dell'acciaio extractolce), G. Sirovich. *La Metallurgia Italiana (Milan)*, vol. 22, no. 7, May 1930, pp. 555-560, 6 figs.

Report from Metallurgical Laboratory of Royal School of Engineering of Rome on experimental study proving superiority of heat treatment over ordinary annealing as generally practiced.

Heat Treatment of Steel and Use of Special Steel in the Machine Industry (Om Varmebehandling av Stal, N. H. Aall. *Teknisk Ukeblad*, vol. 77, no. 27, July 3, 1930, pp. 304-306.

Discussion of plain carbon steel vs. alloy steel with regard to satisfactory control of physical properties by proper heat treatment; ratio of chilling speed to crystallization speed permits conclusions as to whether carbon or alloy steel is more economic.

QUENCHING. The Thermal Analysis of Quenched Carbon Steels. *Fuels and Furnaces*, vol. 8, no. 8, Aug. 1930, pp. 1095-1096, 4 figs.

Discussion of results obtained on quenching steels of various carbon content; evolution of heat; changes in structure of steel.

QUENCHING. Single-Quenching After Carburizing. W. F. Chubb. *Metallurgia (Lond.)*, vol. 1, no. 5, Mar. 1930, pp. 197-199, 11 figs.

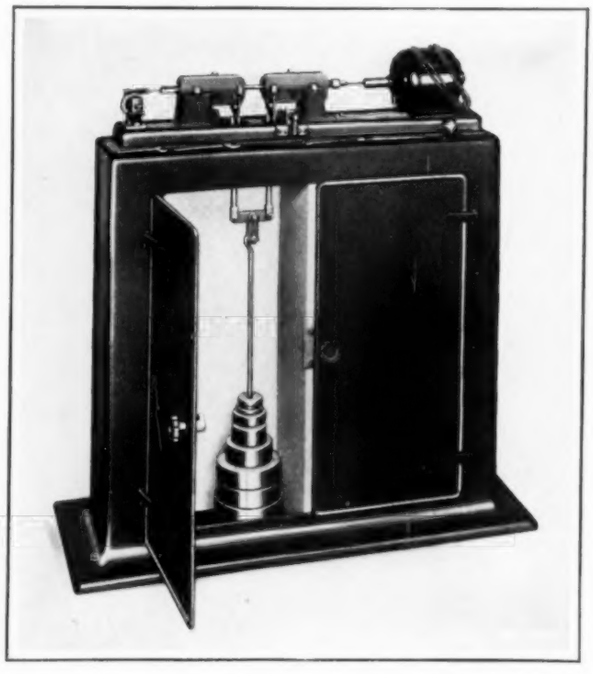
By single quenching is meant hardening of case without necessity of first refining core; present practice of single-quenching is due to influence of nickel in retarding grain growth; general properties of nickel steels; influence of treatment on microstructure of both core and case; satisfactory results can be secured from process of single-quenching after carburizing, but full knowledge of process must be sought.

STEEL TESTING

Effect of Heavy Torsion at Red Heat on Dilatometric Anomalies of Mild Steels (L'influence d'une forte torsion au fouge sur les anomalies dilatometriques des aciers doux), J. Seigle. *Genie Civil (Paris)*, vol. 97, no. 1, July 5, 1930, pp. 6-9, 12 figs.

Further study of anomalies referred to in article by same author, indexed in Engineering Index 1929, p. 1779; study of dilatation and change in arrangement of crystals; mechanism of torsion at red heat; deformation at red hot condition.

(Continued on page 172)



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TOOL STEEL

Defects and Sources of Defects in Mine Tools (Fehler und Fehlerquellen an Grubenwerkzeugen), E. Schumann. *Glueckauf (Essen)*, vol. 66, no. 21, May 24, 1930, pp. 697-704, 16 figs.

Different causes of defects are studied on basis of practical examples; relation of heat treatment to composition of steel; flame sensitivity; materials of unsuitable composition; defects which have their source in steel plant and rolling mill, and those due to incorrect annealing, quenching, etc.

HARDENING. Improvement of Hardness of Normally Heat-Treated Cutting Tools by Cold Hardening (Die Erhoehung des haertegrades normal gehaerteter Schneidwerkzeuge durch Kaltverfestigung), E. Franke. *Werkstattstechnik (Berlin)*, vol. 24, no. 13, July 1, 1930, pp. 360-362, 2 figs.

Description of new surface cold-hardening procedure; graphs show hardness increase for various steels; untreated portion of carbon steel shows Brinell hardness 740, while surface shows hardness of 1920, notes on electromagnetic hardening methods.

TUNGSTEN-CARBIDE CUTTING TOOLS

The Use of Tungsten Carbide as a Cutting Material on Heavy Machine Tools, C. Seller. *Mech. Eng.*, vol. 52, no. 7, July 1930, p. 683-9.

Brief review of experience of early user of tungsten-carbide tools on cast iron; steps taken to introduce this material into machine shop and method used to follow up results obtained; suggestions for grinding procedure, clearance angles, and shapes of tools; difficulties are listed with possible remedies for each; six typical successful applications.

Cemented Tungsten Carbide Progress and Possibilities, F. W. Curtis. *Factory and Indus. Mgmt.*, vol. 80, no. 1, July 1930, p. 44-6.

Composition of cemented tungsten carbide and method of manufacture; its properties and effect upon metalworking industries.

LAPPING. Lapping Tungsten Carbide Tools, H. J. Wills. *Abrasive Industry*, vol. 11, no. 7, July, 1930, pp. 25-26, 2 figs.

How lapping of tungsten-carbide tools can be performed successfully with carbide of silicon which costs only 70 cents per lb.; instead of diamond dust which costs $9,000 to $25,000 per lb.

WELDING

Control of Weld Properties, R. W. Holt. *Acetylene Jl.*, vol. 32, no. 1, July 1930, pp. 17-19, 4 figs.

Interrelation of various factors affecting properties of weld deposits. Paper read before Gas Products Assn., Jan. 20-22, 1930.

Welded Structures. *Metallurgia (Lond.)*, vol. 1, no. 5, Mar. 1930, pp. 207-208 and 213, 5 figs.

Brief review of progress in development of welding processes; new and successful applications.

(Continued on page 176)

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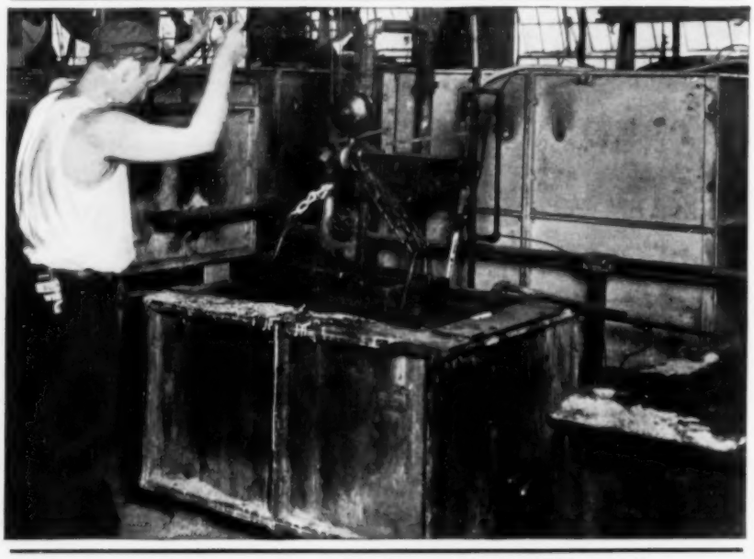

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Welding in Plant Repairs, H. W. Benton. *Power Plant Eng.*, vol. 34, no. 15, Aug. 1, 1930, pp. 886-888.

Use of right methods and equipment by experienced operators cut costs in manufacture and plant upkeep; welding vs. riveting.

Metals and Welding, W. B. Miller. *Am. Welding Soc.—Jl.*, vol. 9, no. 7, July 1930, pp. 98-104.

Usefulness of metals and alloys will increase as ability to weld them increases; welded joints preferable because tightness permits fabrication of apparatus otherwise difficult to manufacture; little information is available as to weldability of numerous alloys used for withstanding various corrosion conditions in chemical industry today; practically all of newer developments in alloys have been carried out with idea of combating some particular corrosion condition; classification of metals, and methods of welding.

WIRE, STEEL

HEAT TREATMENT. Patenting Wire in Gas Furnaces. *Metallurgia (Lond.)*, vol. 1, no. 5, Mar. 1930, pp. 209-210, 5 figs.

Notes on wire manufacture; comparative advantages of basic steel and acid steel; object of patenting is to normalize or regulate grain structure throughout rod; advantages of gas fired furnaces.

COLD HEADING. Cold-Heading Materials, P. Mabb. *Machy. (Lond.)*, vol. 36, no. 926, July 10, 1930, pp. 461-463, 4 figs.

Description of operations and dies used in cold heading and thread rolling of rivets, screws, and similar parts; data are given on properties of mild, carbon, and nickel steel wires, and brass and copper for cold heading.

X-RAY ANALYSIS

Scientific and Industrial Applications of X-Rays (Les applications scientifiques et industrielles des rayons X), J. J. Trillat. *Science et Industrie (Paris)*, vol. 14, no. 197, June 1930, pp. 417-420, 13 figs.

Discussion of general properties of X-rays, absorption, diffraction; description of laboratory equipment; sketches show design of tubes and spectrograph. (To be continued.)

Les Applications des Rayons X; Physique, Chimie, Métallurgie, J. J. Trillat. Paris, Les Presses Universitaires de France, 1930. (Recueil des Conférences-Rapports de Documentation sur la Physique, v. 17) 298 pp., illus., diagrs., 85.-fr.

Modern applications of X-rays in study of physico-chemical and industrial questions are summarized intelligently in this work, and good bibliographies are included; study of states of matter, of metals, cellulose, colloids, rubber, gelatine, and other chemical substances is described, with emphasis upon very recent work; general properties of rays and methods of producing and using them are given briefly in introduction to work.